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POLISH PHYSICAL CULTURE IN GERMANY AND THE GERMAN MINORITY'S PHYSICAL CULTURE IN POLAND UNTIL 1939 – A COMPARATIVE STUDY

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Abstract The article represents the first attempt to depict the similarities and differences in the development of Polish physical culture in Germany and German physical culture in Poland during the interwar period of the 20th century. In both Poland and Germany, up until 1939, national minorities, notably the Germans in Poland and the Polish in Germany, played a significant role in fostering the development of physical culture. Drawing upon scholarly research and archival sources, commonalities between Polish physical culture in Germany and German physical culture in Poland can be discerned. They included: significant politicization, utilization for shaping patriotic attitudes and national integration, activity in the field of physical education, sports, and tourism, similar forms of activity of the Sokół Gymnastic Society in Germany and the German Turner Association in Poland, concern for the development of physical education among children and youth, and support from the respective home countries. However, notable disparities exist, including the longer-standing traditions of German physical culture on Polish soil, the considerably smaller scale of material support from Polish authorities for minorities in Germany, and the involvement of Deutsche Turnerschaft in Poland in a revisionist campaign against Poland in 1939.

Key words German Turner Association in Poland, Polish physical culture, German minority

Introduction

Until 1939, the territory of the Polish state was inhabited by a sizable German population, while numerous Poles settled in Germany. The influx of Germans to Polish lands stemmed from several waves of colonization, with the earliest dating back to the Middle Ages. Conversely, the migration of Polish people to Germany unfolded with a distinct dynamic, primarily occurring in the latter half of the 19th century and continuing until the end of the discussed period. These disparities were rooted in the motivations behind each group's migration – Germans settled in eastern regions as part of colonization initiatives, whereas Poles were driven by economic factors, seeking better financial prospects as they emigrated. The Polish population, often impoverished or facing persecution, found themselves in Germany due to economic and political emigration during the 19th century, and primarily economic

reasons in the first four decades of the 20th century (Kołodziej, 1988). As a result of these historical conditions, the economic circumstances of the German population in Germany were notably more favourable compared to the situation of the Polish population. In Poland, Germans held positions as landowners, affluent peasants, members of the intelligentsia, the bourgeoisie, and prosperous industrialists. This was particularly prominent in areas formerly under Prussian rule and the Łódź district (Dąbrowski, 1977). Overall, from 1918 to 1939, approximately 1.5 million Polish individuals resided in Germany (Wrzesiński, 2005), while the German population in Poland numbered less than 1 million people (Statystyka Polski. Pierwszy Powszechny Spis Ludności Rzeczypospolitej Polskiej z dnia 30 września 1921 r., 1927; Statystyka Polski. Drugi Powszechny Spis Ludności z dnia 9 grudnia 1931 r., 1938; Mały Rocznik Statystyczny 1938, 1939). Serious disputes arose regarding the accurate and precise count of national minorities. The Polish authorities only acknowledged census results, a stance contested by activists of the German minority who asserted that their estimates were twice as high as those provided by Polish data. In Germany, the local Union of Poles (ZPwN) believed that the German authorities deliberately downplayed the number of the Polish population to diminish its significance. Thus, even statistics became a means of diminishing the importance of the German minority in Poland, and conversely, the Polish minority in Germany, as evidenced by the German population census in 1939 (Jacimirski, 1965; Klimaszewski, 2007).

In comparison to the German minority in the Second Polish Republic, the number of Poles in Germany was nearly double, yet concerning the total population, the percentage of Poles in Germany closely paralleled the percentage of Germans in Poland. These disparities extended beyond merely economic advantages, encompassing legal standing and the tradition of promoting the German language that the German minority in Poland enjoyed. It was unilaterally covered by the Minority Treaty of 1919, and it also had significantly greater economic potential, additionally supported by the notorious Deutsche Stiftung and other aid programs (Fiedor, 1973). Polish people did not have such opportunities, protected only in Opole Silesia by the mutual Upper Silesian Convention (1922–1937), and indirectly by the non-aggression pact (1934–1939) and the declaration of non-violence (1937). Even more pronounced disparities were evident in the material circumstances, as Germans residing in the Second Polish Republic generally enjoyed greater wealth compared to Poles living in the Weimar Republic and the Third Reich. Similarly, the advantage in terms of the number of intellectuals was notable, exacerbating the acute sense of lacking among the Polish population in Germany. The Second Polish Republic did not have a tradition of supporting Polish identity and lacked economic opportunities adequate to the needs, so assistance for the Polish community in Germany was rather moral and symbolic, much below the expectations of compatriots in this country, aroused after regaining independence. The consequence of these adverse conditions was an inclination towards a defensive approach, focused on maintaining the existing position and preserving the current potential. Adopting a defensive strategy also exposed Poles to a lesser extent to open conflict with the German authorities and limited losses in the confrontation with the German state. The concept of activities in the realm of physical culture only began to take shape at the juncture of the 1920s and 1930s, emerging as a derivative of the overarching strategy of the ZPwN, which deemed sport as a principal tool for the national education of youth. This vision for the development of physical culture was underscored during the Second Congress of Poles from Abroad in 1934, wherein physical culture was designated a pivotal instrument for promoting Polish identity through Polish sports associations and youth organizations (Orzechowski, 1967; Woltmann & Jurek, 2002).

A comparative analysis of the development of physical culture among the German minority in the Second Polish Republic and the Polish minority in Germany during the years 1918–1939 reveals intriguing similarities and

notable differences in the evolution of gymnastics, physical education, sports, and tourism within these demographic groups. This topic has been largely overlooked in the historical literature, as prevailing narratives tended to focus on separate strands without connecting these seemingly disparate issues. However, it becomes apparent that the physical culture of national minorities in Europe during the interwar period shared numerous common features that have hitherto been neglected in scholarly discourse. Of particular significance was the attention given to this domain in both Germany and Poland, given the sizable presence of individuals from neighboring countries within their borders. Nonetheless, Polish and German scholars have largely overlooked this subject. This article draws upon archival materials from Polish and German institutions, supplemented by existing literature. The research employs historical source analysis and the comparative method (Topolski, 1973).

"Sokół" Gymnastic Society and the German Gymnastics Association

The "Sokół" Gymnastic Society played a paramount role in the realm of Polish physical culture, effectively transmitting the noble ideals of patriotic education from Polish territories to their groups in Germany. "Sokół" operated the longest and developed the richest repertoire of various pro-Polish activities. Its activity within the German state lasted half a century and significantly contributed to protecting its members and supporters from Germanization. Moreover, the Gymnastic Society set a compelling example for other sports and tourist organizations through its systematic efforts to uphold national identity. At its zenith in 1914, there were 182 "Sokół" groups in Germany, boasting 7,302 members. However, during the interwar period, both the number of groups and members dwindled. The largest number of groups, amounting to 141 with 4,531 members, was recorded in 1922. The effective operation of "Sokół" was evidenced by German apprehensions and the harassment endured by its members. Indeed, German authorities regarded "Sokół" as the most perilous, political, and militaristic Polish organization, deeming it highly detrimental to the German state and thus subjecting it to constant surveillance. Sports clubs established at the outset of the 20th century and continuing their operations until the end of the discussed period also made significant contributions to the achievements of Polish physical culture. In Germany, TG "Sokół" was dubbed a "military-civic school of Polish knights," which, "along with other sports associations, was predominantly engaged in fostering Polish-nationalist consciousness" (Ueberhorst, 1992, "Orędzie Sokole" 1921, no 1).

The Turner movement constituted the primary domain of activity for Germans in Poland within the realm of physical culture. In 1921, the Turners consolidated under the German Gymnastics Association in Poland (DTP), with full integration of all gymnastic societies and certain sports clubs ultimately achieved in 1935. Jakub Jung, serving as the longstanding chairman of DTP, played a pivotal role in this process. As early as the spring of 1933, DTP unequivocally endorsed Nazi governance in Germany and, "as a reward," was tasked with unifying all physical culture organizations in Poland. DTP also received financial backing from the German Foundation (Deutsche Stiftung). Despite strenuous efforts between 1935 and 1938, a unified German Turner and Sports Association failed to materialize in Poland. Against the backdrop of the successes of the Turner movement in Czechoslovakia and the effectiveness of Konrad Henlein, regarded as a role model for Germans in the Second Polish Republic, the position of DTP was considerably weakened, as it encompassed less than 1% of all Germans in Poland. Notable centres of conversion in Poland included Bielsko, Bydgoszcz, Chorzów, Katowice, Łódź, Poznań, and Toruń (Federal Archives Berlin. Deutsche Stifung, no. 447; Fiedor, 1973; Jurek, 2002).

In comparison to the German minority in Poland, although the number of "Sokół" groups in Germany was higher, but overall they collectively comprised a smaller number of members. Furthermore, during the interwar

period, the number of "Sokół" TG groups and members in Germany declined, while the count of Turner societies and their members in Poland doubled by 1939, reaching 5,672 members as of January 1, 1939 ("Mitteilungen der Deutschen Turnerschaft in Polen", 1926, no. 6, 1931, no. 4, 1936, no. 3, 1939, no. 1; "Sprawy Narodościowe", 1929, No. 2; Gasch, 1923). The traditions of the German Turner movement in Poland are markedly older and more extensive than the tradition of "Sokół" in the Second Reich. While the first Turner society in Poland was established in 1815, the inaugural association of the "Sokół" Gymnastic Society in Germany only emerged in 1889 – seven decades following the establishment of the society in Pszczyna and two decades subsequent to the inception of the first "Sokół" TG on Polish lands in 1867 in Lviv (Ryfowa, 1976). This chronological discrepancy had implications for the delayed development of "Sokół" in Germany relative to its development in Poland. During the interwar period, the number of "Sokół" groups in Germany and Turner societies in Poland were comparable, with similar levels of scope and activity (Wyskok & Jurek, 2018).

Sports clubs

Sports clubs established in the early 20th century and persisting until the end of the discussed period made a notable contribution to the advancement of Polish physical culture in Germany. These clubs served as focal points not only for sporting activities but also for comprehensive national endeavours. They facilitated numerous gatherings, cultural events, social evenings, and other activities. Sport served as a pretext for fostering the aforementioned forms of engagement and was not solely viewed in terms of athletic achievement. While sports outcomes held significance, even greater importance was placed on accompanying events, creating a sort of ritual around sporting events. Among the Polish sports clubs operating in Germany, those from Berlin, Silesia, Rhine-Westphalia, and the former border regions held particular prominence. With the influx of Polish emigrants into Germany, numerous groups of the proletariat emerged, particularly in industrial hubs such as Silesia, the Ruhr area, and Saxony. It was within these groups that workers' sports associations were established, representing essentially class-based forms of physical culture. Notably active in Silesia was the Federation of Polish Workers' Sports Clubs, founded in 1934, which later evolved into the Federation of Polish Sports Clubs "Siła." In 1936, a total of 1,324 members were enrolled across 14 workers' sports clubs. According to their principles, these organizations primarily attracted workers, although they also welcomed craftsmen and individuals from outside the working class. The milieu of Polish workers' clubs in Germany attained a relatively elevated status compared to German workers' sports associations in Poland. The latter faced numerous challenges, including size constraints and encounters with hostility from Nazi authorities between 1933 and 1939. The Polish workers' movement in Germany surpassed the presence of German workers' societies in Poland, with the latter comprising only 7 sections. However, the number of members within these sections was twice as large (2,800 members in 1931), compared to the associated Germans in workers' sports organizations in the Second Polish Republic. This advantage in both club numbers and membership stemmed from the fact that the working environment of the Polish minority in Germany was substantially larger in comparison to the concentrations of the German proletariat in the Second Polish Republic. The numerical advantage of Polish workers in Germany over German workers in Poland translated into the scale of workers' sports, which was proportional to the greater numerical potential of the Polish proletariat in Germany (Jurek, 2002; Grańska & Jurek, 2015).

The German sports movement in Poland achieved a high level of organization, with athletes attaining significant national and international successes. The development of sports was different, based on large clubs that had considerable independence and were not as flexible as the Turner movement. Some clubs in Pomorze

and Wielkopolska even established their own associations. For instance, the Poznań-Pomorze Rowing Association united five rowing societies, led by the largest one, RC "Frithjof" Bydgoszcz. Similarly, West Pomeranian Cycling Federation, headquartered in Nowy Tomyśl, played a similar role, uniting 30 small cycling societies from neighbouring towns. Rowing flourished primarily in Pomorze, while cycling thrived in Wielkopolska. Conversely, football gained immense popularity in Upper Silesia and Łódź, with clubs like I FC Katowice and "Union" Łódź ranking among the best in Poland. Notably, Katowice produced some of the finest Polish swimmers, including Ilse Boll, Helmut Barysz, and Joachim Karliczek from EKS Katowice, as well as talented water polo players from the same club. In Łódź, notable talents emerged in tennis, with multi-medallist champions such as Wera Richter and the Stolarow brothers, Jerzy and Maksymilian. German athletes made significant contributions to Polish sport achievements, with players like Ernst Wilimowski from I FC and Fryderyk Scherfke from "Warta" Poznań representing Poland at the 1938 World Championships. Eight German athletes proudly represented Poland in the Olympic team across various sports including cycling, football, swimming, and skiing. The best athletes in Poland also excelled in boxing, weightlifting, basketball, motorcycling, and wrestling (Jurek, 2002).

It is worth noting that the clubs operated under different conditions. Despite the enormous material pressure and ideological influence of the government in Berlin, some sports clubs retained considerable independence and subjectivity. They resisted the pressures of the Gleichschaltung campaign in the 1930s and did not become tools of the Third Reich authorities. This group encompassed rowing clubs, cycling societies, and clubs with football sections. The workers' sports associations, united in their own ATSBP union, completely independent of Berlin, went the furthest in opposing the organizational and program directives. Concentrated mainly in Silesia, these workers' associations found themselves in ideological conflict with the majority of Turner and sports associations, which leaned towards a bourgeois and nationalist orientation. While DTP and most clubs aligned with Nazism, workers' associations were ostracized by their compatriots and Poles, gradually diminishing in significance by the end of the discussed period (Jurek, 2004).

German sports organizations in Poland and Polish associations in Germany began emerging around the same period. Comparatively, Polish clubs in Germany outnumbered German clubs in Poland in terms of both their quantity and membership. However, German clubs in the Second Polish Republic demonstrated a higher level of sports training among their members. This was evidenced by their considerable success in major national competitions, including the Polish championships, as well as the notable participation of eight German athletes in the Summer and Winter Olympic Games between 1924 and 1936. The top athletes in Poland during this period excelled in various sports such as skiing, swimming, water polo, football, cycling, tennis, and rowing. The achievements of Polish club athletes in Germany in competitive sports are much more modest. They could not boast of valuable achievements as the activities of Polish associations were dominated by recreational forms, and sports results were placed on the back burner, with less importance attached to them.

Physical education in schools

Between 1918 and 1939, a significant struggle ensued for the establishment and maintenance of Polish schools in Germany, where physical education classes, as well as sports and tourist extracurricular activities, were conducted. This dispute over the Polish school system particularly impacted the Polish-German border regions, where sports activities were notably active. In addition to the utilitarian and preventive role of physical education, considerable emphasis was placed on maintaining a high standard of classes in this subject and sports, infusing

both lessons and extracurricular activities with an educational and pro-Polish character. The number of Polish schools in Germany fluctuated during this period. Following an initial increase in their number, there was a decline in the 1930s, especially in the latter half of that decade. All students attending Polish schools were required to participate in compulsory physical education lessons and additional extracurricular activities as per the school curriculum (Archive of New Files [Archive of New Files Warsaw]. The Ministry of Religious Affairs and Public Education, No. 162).

Until 1939, physical education and sports in German schools in Poland enjoyed a privileged status, surpassing not only the number of German schools in the Second Polish Republic but also in achievements related to promoting recreation during physical education lessons and accomplishments in school sports. This superiority was attributed not only to the richer tradition of physical education in Prussian education but also to the more limited resources and less professional teaching staff in the Polish education system. Physical education, coupled with sports activities, was intended to foster the "German spirit" among children and young people. German schools implemented a curriculum that included two hours of physical education classes per week, with some schools offering up to four lessons. Private schools, particularly junior high schools, boasted the best faculty and facilities, underscoring the importance placed on physical education and school sports. Similar level of development was achieved in contacts between Polish schools in Germany and between German schools in Poland in the field of school sports (Jurek, 2020).

Tourist movement

In addition to physical education and sports, tourism remained a significant aspect of physical culture during the interwar period. The resurgence of an independent Polish state was a driving force behind this trend, encouraging Poles from various countries, including Germany, to visit their homeland. There were also families of many emigrants living in the homeland, which - apart from historical places and religious centres - were the destinations of individual and group visits. Moreover, summer camps for Polish children from Germany, particularly those from industrial centres, played a crucial patriotic and educational role (Jurek, 2014). The 1st Polish Olympic Games, held in Warsaw in 1934, served as a notable and distinctive tourist attraction for Poland. This unprecedented sports and tourism event brought together 381 participants from 12 countries worldwide, as well as the Free City of Gdańsk, including representatives from the German Polish community. While the sporting outcomes of the Polish diaspora competitions were not paramount, Poland emerged as the moral victor of the games, as emphasized at the time (Pierwsze Igrzyska Sportowe Polaków z Zagranicy, 1934; Rotkiewicz, 2005).

Tourism played a significant role in upholding national values among the German population in Poland. Noteworthy among tourist organizations were the Beskid Society based in Bielsko, boasting over five thousand members, and the Wanderbund, which operated throughout the country. Other notable tourist organizations included the "Wędrujące Ptaki" (Wandervögel), the Upper Silesian Tourist Association (Oberschlesischer Wanderbund), the Tourist Association (Turisten Verband), "Przyjaciele Przyrody" (Naturfreunde), primarily active in Silesia, as well as Union-Touring Łódź and the Alpine Society (Alpenverein). All these organizations fostered a strong connection to their homelands (Heimat - Little Homeland) and advocated for active recreation, particularly in the mountains. They vehemently opposed any Polish attempts to encroach upon their territories. This was notably evident in the prolonged conflict over tourist trails and mountain shelters between the Beskid Mountains Society and the Polish Tatra Society, which persisted throughout the interwar period of the 20th century (Jurek, 2008, Jurek, 2010).

A comparison of tourism between the Polish population in Germany and the German population in Poland reveals an intriguing observation: Polish tourist visits to their homeland were more widespread and frequent compared to the corresponding activity of the German population in the realm of tourism. The aforementioned 1st Polish Sports Games, unparalleled in other countries, including Germany for the German minority from Poland and elsewhere, garnered global attention. To some extent, the monumental German Sports Festivals, held in 1933 in Stuttgart and in 1938 in Wrocław, served as a counterweight. The latter event, in particular, carried significant propaganda implications, featuring the participation of approximately 500 German athletes from Poland in this Nazi showcase event - second only to the Olympic Games in 1936 (Jurek, 2000).

Other similarities and differences

The development of physical culture varied across different regions of Germany and Poland. Disparities were influenced by factors such as the financial circumstances of the Polish population and the traditions of falconry, physical education, sports, and tourism. In Germany, distinct areas of significant Polish activity in the realm of physical culture were evident. These regions typically aligned with the districts of the Association of Poles in Germany and the largest centres of Polish population. Here, Polish youth organizations, Sokół societies, sports clubs, and Polish schools played pivotal roles in promoting physical education, sports, and tourism. The most vibrant region in terms of physical culture was Silesia, particularly notable for the active presence of the Sokół movement, workers' clubs, and youth organizations. This activity encompassed the entire Opole region and the German part of Upper Silesia, forming a dense network (Szczerbiński, 1987). The second active area was the central part of Germany (Berlin, parts of Brandenburg, and Saxony), where the first centers of the "Sokół" Gymnastic Society were established, alongside a total of 6 Polish sports associations. Rhineland-Westphalia also exhibited significant potential in the realm of physical culture, boasting various activities in this field, albeit lacking workers' sports associations. Additionally, Polish physical culture made strides in Masuria, Warmia, and Powiśle, particularly thriving in Masurian Mazovia. In total, 39 sports organizations were established in the area, fostering physical education, sports, and tourism. The former border area had the fewest sports organizations, attributed to the widespread dispersion of the Polish population and significant distances between individual small groups of Poles, primarily engaged in agriculture. However, Krajna Złotowska and Babimojszczyzna stood out as positive exceptions in this regard (Jurek, 2013).

In Poland, German physical culture thrived primarily in the regions of the former Prussian partition, encompassing cities and even small towns in Wielkopolska and Pomorze. Among the most renowned centres of the Turner and sports movement in these areas were: Bydgoszcz, Chojnice, Grudziądz, Leszno, Nowy Tomyśl, Poznań, Rawicz, and Toruń. Additionally, Turner societies and sports clubs in Upper Silesia and the Łódź district displayed notable activity. Major Silesian hubs of German physical culture included: Bielsko, Chorzów, Cieszyn, Katowice, Lipiny, Mysłowice, Pszczyna, Rybnik, Siemianowice, Szopienice, and Świerklaniec. In the Łódź district, Łódź stood out prominently in this regard, with gymnastics and sports associations also thriving in Aleksandrów, Konstantynów, Pabianice, Tomaszów, and Zgierz. In other parts of Poland, characterized by "language islands" (Sprachinsel), the German population did not actively participate in physical culture, with the sole exception being the "Vis" Lviv sports club (Jurek, 2002; Urban, 2006).

When conducting a further comparison, it is crucial to consider the political conditions that shaped the development of German physical culture in Poland and Polish physical culture in Germany. During the discussed

period, Poland emerged as a relatively politically stable and predictable country guided by democratic principles, particularly towards national minorities. In contrast, Germany in the interwar period initially upheld democratic values and pursued a balanced policy towards national minorities. However, following the rise of the Nazi regime in 1933, attitudes towards all national minorities gradually deteriorated. This deterioration escalated into hostile actions towards the sports and tourist activities of the Polish population in 1938–1939 (Szczerbiński, 1987).

Stages of development of physical culture of national minorities in Poland and Germany

The comparison of distinct stages in the history of German physical culture in Poland and Polish physical culture in Germany offers intriguing insights. In the development of German physical culture on Polish lands and in the Second Polish Republic, several significant stages emerge, influenced by the status of the German population under partitions, the state of Polish-German relations, internal developments in Germany, and to a lesser extent, the policies of the Polish authorities. The first stage unfolded during the years 1918–1921, a tumultuous period for both neighbouring countries as they delineated their common border. The numerous conflicts of that time, including the Silesian Uprisings, the Greater Poland Uprising, and plebiscites in disputed regions like Upper Silesia and Warmia and Mazury, did not foster the resurgence of the Turner and sports movements. The activities of reactivated societies and clubs were marred by numerous conflicts, particularly prevalent in Silesia, where in the aftermath of the uprisings, armed incidents against athletes, mutual terror, and sabotage of German sports events were common occurrences. The revitalized Turner sports movement encountered the significant challenge of post-war emigration to Germany, which, coupled with previous war losses, depleted the ranks of physical culture associations. In regions like Silesia, Pomorze, and Wielkopolska, the loss of members amounted to as much as half of the pre-World War I numbers. Despite these difficulties, the Turner movement was reborn, developed and consolidated for the first time at the end of 1921, creating a still small but extremely important nucleus of the future nationwide organization in Wielkopolska and Pomorze. The second stage covers the years 1922–1925, when, in the conditions of post-war stabilization, German physical culture developed within Turner societies, sports clubs, tourist societies, as part of school activities and minority organizations. During this period, a campaign of material support from Germany was initiated. This stage was crowned by the merger in 1925 of the two existing DTP districts with the Silesian district into the National Turner Association, which stretched, as it proudly claimed, “from the Baltic Sea to the Beskids”. The third stage, covering the years 1926 to 1932, saw further progress in the sports movement. Athletes excelled in various sports such as football, swimming, and tennis, actively participating in national competitions and demonstrating a high level of sporting prowess. The opposite trend was observed in Turnerism, which, despite reaching its organizational peak at the turn of the 1920s and 1930s, experienced stagnation in the number of societies and their membership. This was attributed to the nationalist nature of the Turner movement and the absence of sports exchanges with Polish associations during this period. Meanwhile, a campaign to train instructors began in Germany and the Free City of Gdańsk. The fourth stage, spanning from 1934 to 1938, witnessed a rapprochement between Poland and Germany. The significant emphasis placed on physical culture in the Third Reich influenced the development of German physical culture abroad, including in Poland. Consequently, there was an increase in contacts between German associations in Poland and teams from the Reich. The activity strategy was shaped by the principle of Gleichschaltung, aiming for the unification of all physical culture in line with Nazi ideology. In Poland, the authorities in Berlin designated the main organization as DTP, but attempts to unite all sports organizations under this banner failed, leading to fragmentation in German physical culture. The final stage in the

history of German physical culture occurred during the crisis period before the outbreak of World War II, particularly evident in 1939 when the bilateral treaty expired. The activities of German gymnastics societies and sports clubs became increasingly marked by revisionism and anti-Polish slogans. While previously restricted by official German authorities, these sentiments gained momentum just before the war. However, they were still suppressed, allowing German gymnastic, sports, and tourist associations to operate without major obstacles (Jurek, 2002).

In the development of Polish physical culture in Germany, the first stage covers the period from the establishment of the first branch of the Gymnastics Society "Sokół" in 1889 to the outbreak of the First World War in 1914. During this time, branches of the Gymnastics Society "Sokół" were founded, organizational structures of this association were established, the first Polish sports clubs were founded, and pioneering forms of sports competition took shape. The second period concludes within the timeframe of the World War I, when activity in the field of physical culture practically ceased. Sokół members, as well as members of Polish sports clubs, became victims of the Great War (Blecking, 1987). The subsequent period spans the existence of the Weimar Republic and is closely associated with the establishment of the Association of Poles in Germany in 1922, which brought together most Polish organizations, including sports clubs. The final stage in the history of Polish physical culture occurred during the Third Reich and lasted until the outbreak of World War II. Despite the bilateral treaty on non-aggression between Germany and Poland signed on January 26, 1934, there was a gradual deterioration in the conditions of Polish national activity in Nazi Germany, with a particularly challenging final period of open hostility in 1938–1939. This period witnessed a crisis in the "Sokół" Gymnastic Society and a weakening of the sports movement, accompanied by a reduction in the scope of physical education in Polish schools. Poles suffered repression during this time. The analysis of the presented stages leads to the conclusion that Polish physical culture in Germany encompassed the Sokół movement, Polish sports clubs of various origins, youth organizations, particularly scouting, and organized as well as individual tourism. It evolved within three political systems: the Hohenzollern monarchy (until 1918), the democratic Weimar Republic (1918–1933), and the totalitarian Third Reich (1933–1939). None of these regimes actively supported the national activities of Poles in the realm of physical culture, and during the final period of the Third Reich, there were even attempts to completely eradicate Polish sports, tourism, and physical education in schools. In such initially complex and increasingly difficult conditions since 1933, Polish physical culture in Germany served not only hedonistic and utilitarian purposes but primarily fulfilled national and patriotic objectives. German physical culture in the Second Polish Republic initially served a national function, which later evolved into a revisionist one (Chałupczak, 1992; Jurek, 2013).

Conclusions

When evaluating Polish physical culture in Germany until 1939, it is crucial to consider the intricate circumstances under which the Sokół movement, sports initiatives, physical education, and tourism developed. It is important to recognize that Poles faced not only the challenge of natural assimilation but also the significant threat of organized Germanization on a national level. Preserving Polish identity emerged as the paramount objective of Polish diaspora efforts, conducted across various spheres: political, economic, social, educational, cultural, religious, among others. Physical culture played a significant role in nurturing pro-Polish consciousness. The emergence of the Polish national movement coincided with the inception of falconry, sports movements, and tourism in exile. Physical culture activities proved to be as appealing to young people as other forms of organizational work. Physical education, sports, and tourism served as valuable and popular platforms for fostering national

sentiments and cultivating patriotism and resilience in the face of harsh persecution, particularly during the late 1930s under the reign of Nazism. Poles were deprived of their rights, subjected to constant surveillance, and sentenced to what was termed "statistical death," foreshadowing the tragedy and the ultimate sacrifice that many Rodło activists paid during World War II for their earlier Polish diaspora endeavours.

When assessing German physical culture in Poland, it is crucial to consider the prevailing strong nationalism during the Third Reich and the increasingly revisionist stance towards Poland. Physical culture was strategically employed by the Nazi authorities in Germany and among the German minority in Poland as a platform for national activity fuelled by a spirit of revanchism for perceived „grievances" stemming from the Treaty of Versailles. The German Gymnastics Association in Poland played a significant role in this process. Consequently, Adolf Hitler justified aggression against Poland and the onset of World War II by citing alleged injustices against the German population, which were often fabricated and utilized for propaganda purposes. The physical culture of the German population flourished in the Second Polish Republic without significant hindrances, albeit overshadowed by escalating chauvinism and instrumentalization by German authorities. Nevertheless, it is important to acknowledge the positive aspects, particularly the substantial contribution of German athletes to the successes of the Polish Olympic movement and sports in Poland. In this regard, German athletes notably surpassed their Polish counterparts in Germany, where recreational activities predominantly prevailed and the level of sportsmanship remained low.

In summary, it can be concluded that there were notable similarities as well as distinct differences in the development of Polish physical culture in Germany and German physical culture in Poland. Common features included strong politicization, the utilization of gymnastics, physical education, sports, and tourism to foster patriotic sentiments and national integration. Both regions witnessed similar activities in physical education, sports, and tourism, with analogous forms of engagement by organizations like the "Sokół" Gymnastic Society in Germany and the German Turner Association in Poland, along with ongoing efforts to promote physical education among children and youth with support from their respective home countries. Significant differences included the much longer and more robust traditions of German physical culture on Polish soil, the comparatively lesser material support from Polish authorities for minorities in Germany, and the involvement of the Deutsche Turnerschaft in Poland, along with certain sports organizations, in an anti-Polish campaign in 1939.

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SOMATICS AND PHYSICAL FITNESS OF SELECTED MILITARY CLASSES

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Abstract The idea of opening military classes refers to the tradition of national defense education, training the young generation to defend the homeland and strengthening the country's ties with the army. The creation of military classes became a precedent for the Ministry of National Defense and the Ministry of National Education to build a common defense education system for high school students. The task of military classes in Polish high schools is to prepare young people for future service in various services, such as police, fire brigades and other special services. The aim of this work is to capture the relationship between body composition components and physical fitness of selected uniformed groups. The body composition components were analyzed with the help of the Tanita Body Composition Analyzer DC-240MA. The study used tests from the Polish Army physical fitness test, the Beep test and barbell bench press while lying on a straight bench. One of the conclusions obtained was that the

correlation between body composition and fitness tests showed that higher levels of body fat, lean body mass, BMI and body weight negatively affect the results obtained in pull-ups, trunk bends, shuttle runs and Beep tests.

Key words: military classes, body composition, physical fitness, beep test

Introduction

The idea of opening military classes refers to the tradition of national defense education, training the young generation to defend the homeland and strengthening the country's ties with the army (Odziemkowski, 1996). The creation of military classes became a precedent for the Ministry of National Defense and the Ministry of National Education to build a common defense education system for high school students (Kaliński, 2000). The task of military classes in Polish high schools is to prepare young people for future service in various uniformed services, such as police, fire brigades and other special services. They are aimed at developing the skills, values and competencies necessary to work in these professions and at shaping patriotic and civic attitudes. The current popularity of military classes in combination with objective, standardized recruitment criteria and attractive programs are conducive to the implementation of ambitious didactic and educational goals. Achieving these goals depends to a large extent on the cooperation of schools and military classes with military units and other organizational units of the ministry or on the support of the local community. It also depends on the commitment and knowledge of teachers conducting military classes and the values that characterize students in these classes (Kanarski et al., 2016). The concept of human physical fitness is interpreted and defined differently depending on the person. Unification of this phenomenon is impossible, therefore definitions on this subject from different authors should be adopted here. The basic motive for examining fitness as a whole of human behavior, abilities and motor needs is the desire to increase the efficiency of human movement, to improve the teaching of movement and its use as a means of stimulating development (Grabowski, 1997). Physical fitness is an ambiguous concept. According to Przewęda (1985), it is possible to interpret it as an ambiguous concept by assigning at least four interpretative approaches: motor, mechanistic-biological, behavioral-cultural and health. The best known and popular in Poland, especially in the theory of physical education, is the method of defining fitness, proposed in the behavioral and cultural convention. This shows that the authors consider a fit person as a person "who has a specific potential of capabilities (is able to), skills (can) and motivation (want), allowing him/her to function properly in specific environmental conditions" (Przewęda, 1985). Clarke claims that physical fitness is: "the ability to conduct all-day activities with vigor and briskness, without excessive fatigue and with a lot of energy needed to spend time pleasantly in various and often unpredictable situations" (Clarke & Clarke, 1978). Physical fitness has been recognized as a key determinant of a healthy lifestyle, increasingly based on criteria related to general health, not just mobility. It has a positive effect on the circulatory and respiratory system, combats general and abdominal obesity, helps strengthen bones and prevents depression and anxiety (Ortega, 2007). The recommendations of the World Health Organization (WHO) are that children and adolescents should perform at least 60 minutes of moderate or high-intensity physical activity every day to maintain good health and maintain a healthy weight (Hallal, 2012). For Howley and Frank the goal of physical fitness is preventing the risk of diseases. "The goal of physical fitness is positive physical health, which determines a low risk of health problems. Achievements are aimed at the ability to engage in daily tasks with adequate energy and satisfactory participation in selected sports" (Howley & Frank, 1997). Physical fitness as the ability to effectively

cooperate with the physiological functions of the body, allows you to perform everyday activities using little effort, and at the same time is a requirement to maintaining health. An able-bodied person is able to work at school, do housework and still has enough energy to practice sports and other forms of spending free time (Haible et al., 2020; Shen et al., 2021). At the same time, undertaking moderate or intense physical activity increases physical fitness and may contribute to reducing sedentary behavior and improving positive health indicators (Knudson & Brusseau, 2022; Mancha-Triguero et al., 2019; Ljach, 2003; Fugiel et al., 2017). It is also understood as the general ability to safely perform everyday activities (Rydzik & Ambroży, 2021). Its level depends on complex genetic factors and physical activity. It includes a number of specific components that kinesiology experts are interested in (Knudson & Brusseau, 2022). A high level of physical fitness is a key element of effectiveness in sports competitions. Knowing the level of their competitors, coaches can choose appropriate training loads, i.e. types of exercises, their quantity and quality. In addition, regular fitness level measurements can help evaluate training effects (Mancha-Triguero et al., 2019). General physical fitness determines the motor skills of the human body. Motor skills are individual psychophysical properties that determine the level of motor abilities (Ljach, 2003). They are a group of predispositions conditioned genetically and shaped by environmental conditions (Fugiel, 2017). Motor skills are most often defined on the basis of strength, speed, endurance, agility and power (Bielski, 2012). They are often related to each other and to other determinants of performance in a given sport (Bora, 2020). When reviewing the literature related to fitness testing, you will come across a wide variety of research studies. In one such study, soldiers from the Croatian Navy were tested. The aim of the study was to determine the influence of body weight on fitness tests of personnel. The research group consisted of 42 members of the navy. To assess the fitness of soldiers, a test procedure was used, which included 7 fitness tests and 15 anthropometric body measurements. A negative correlation was found between body fat percentage and all analyzed sprint trials and three anaerobic power tests. Body fat content was also not significant in performance tests on $\dot{V}O_2max$. A positive correlation was found between the sprint test and the measurement of thigh and calf circumference. Ectomorphic somatotypes have positive correlations with all variables. Mesomorphic somatotypes have the greatest positive correlations with all variables. Endomorphic somatotypes have negative correlations with all variables. Based on the body composition of Croatian navy soldiers, it can be concluded that they need a sufficient level of strength and endurance to perform daily tasks (Kosmalski et al., 2014). Kosmalski et al. conducted a study aimed at evaluating the somatic features and motor skills of 6th class students of primary school in Szubin. The research group consisted of 25 boys and the same number of girls. Fitness level was assessed by ICSPFT, and body weight and height were measured to calculate BMI. As a result of the research, it was shown that children from primary school no. 2 in Szubin are characterized by a higher body weight and shorter height than the average from national surveys. The research group is also characterized by a higher level of strength and lower endurance than the national average (Pletcher et al., 2023). The author of the research conducted on the marines investigated the impact of body composition on the results of a combat fitness test. The research group consisted of 210 men and 84 women aged 20 to 26. The Marine Corps designed the Combat Proficiency Test (CFT) to emphasize functional fitness related to operational requirements. The purpose of this study was to investigate the relationship between body mass (BM), lean mass (FFM) and body fat percentage (BF%) as measured by air displacement plethysmography. The Kruskal-Wallis test or one-way analysis of variance was used to determine whether there were significant differences in total scores and CFT components between the study groups divided into the BM, FFM, and BF% quintiles. There were no significant differences in CFT scores between male and female BM quintiles and no significant differences in CFT scores between male FFM quintiles.

However the CFT total score was significantly different between BF% quintiles in men and significantly different in women. Marines in the quintile with the lowest BF percentage had better CFT scores than those in the higher quintiles (Mendoza-Muñoz et al., 2020). The study of another author was aimed at examining the relationship between body composition and physical fitness of adolescents and analyzing whether there are differences in physical condition and body composition between the sexes. A group of 225 teenagers was examined, including 108 boys and 117 girls. Body weight status was classified according to WHO 2007 standards and included variables such as BMI, body fat mass, body fat percentage and body fat free mass. As part of the physical fitness test, a standing long jump was performed, as well as a test for speed, agility, circulatory and respiratory capacity, and grip strength. There were significant gender differences in body composition (FM%, FM and FFM) and physical fitness in favor of men. Significant differences were also found in speed and standing long jump in favor of adolescents with normal body weight compared to adolescents with overweight and obesity. The results showed that cardiorespiratory fitness and standing long jump correlated inversely with BMI, FM% and total FM. There was also a direct relationship between speed and agility and body fat mass, as well as between grip strength and lean body mass (Sterkowicz-Przybycień, 2019). Farina. et al. conducted research during special forces training of US Army soldiers. The aim of the study was to determine whether anthropometry and body composition affected physical fitness and selection for special forces training. Body height, weight and BMI were measured as well as body composition measured by dual energy X-ray absorptiometry (fat percentage, fat mass, fat free mass, bone mineral density [BMC] and bone mineral density [BMD]). Lower body fat percentage and fat mass predicted better results across all assessments: military fitness test (APFT), pull-up bar, SFAS run, weighted road walking, obstacle course and land navigation. Higher fat-free mass predicted better weighted road walking performance. Lower body weight and BMI predicted better APFT, pull-up, running, and obstacle course. Higher body weight and BMI predicted better weighted street walking. Effects were the best for lean body mass and body fat percentage. Anthropometry and body composition have been shown to influence performance and the success of SFAS (Farina et al., 2022).

Aim of the paper

The aim of this work is to capture the relationship between body composition components and physical fitness of selected military classes . Based on the purpose of the work, research questions were formulated. What are the differences in body composition between the two military classes Do body composition components affect the results achieved during fitness tests? How do the results of physical fitness differentiate diagnosed military classes?

Material and methods

This study was carried out on a group of 23 men from uniformed classes from the Secondary School in Leżajsk. The subjects were 11 students from the first class and 12 students from the fourth class. In the military class, each student fulfills (weekly) four hours of physical education and two hours of specialized classes for military classes. Due to the specificity of their profile at school, the students included in the study do not have any contraindications to practicing sports and are fully healthy. Before starting the research, each respondent was informed about its purposefulness and that the research was fully anonymous. The tests were performed with prior parental consent.

The average body weight of the respondents from the first class was 68.7 kg. The minimum weight is 54 kg and the maximum weight is 80.4 kg. The value of the population standard deviation was 9.33. The body height

of the subjects oscillated between 172 cm and 184 cm, with the average being 177.5 cm and the deviation from the average being 3.50.

The average body weight of the subjects in the fourth class was 82.5 kg. The minimum value for men in the fourth class is 68.8 kg and the maximum is 101 kg. The deviation from the norm was 9.14. The body height of the respondents oscillated between 173 cm and 193 cm. Their arithmetic mean was 183.1 cm and the deviation from the mean was 6.03.

Research method

The research took place at the Secondary School in Leżajsk from 12 to 16 September 2022. Body composition components and fitness tests of the surveyed students were carried out during physical education classes in the school gym, on the pitch and in the sports hall. During the tests, the students were dressed in sports outfits and fitness tests took place after a 10-minute general warm-up.

Measurements of body height and body composition were taken without shoes and without socks in order to thoroughly examine all components. The body composition components were analyzed with the help of the Tanita Body Composition Analyzer DC-240MA and the evaluation is given:

- total body weight,
- body mass index (BMI – Body Mass Index),
- percentage of body fat (Fat %),
- body fat mass (FM – Fat Mass),
- lean body mass (FFM – Fat Free Mass),
- muscle mass in the body (MM – Muscle Mass).

The study used tests from the Polish Army physical fitness test, the beep test and barbell bench press while lying on a straight bench.

The study included the following trials:

- High bar pull-ups

The bar was attached to ladders in the gym at a height of 220 cm. At the "ready" command, the trainees took the starting position of the exercise in a hanging overhand grip with straightened elbow joints. At the signal of the examiner, the trainee began to perform pull-ups. A correct pull-up was counted when the chin line was crossed over the bar and the elbow joint was fully straightened. During pull-ups, the strength of the back muscles, upper limbs and their endurance are assessed.

- Trunk bends in 2 minutes

The exercise is performed lying on the back on the mat with the feet attached to the lower rung of the ladders. The legs are bent at the knees and the intertwined arms are placed behind the head. On command, the trainee starts to perform the exercise. An exercise performed correctly is when the exerciser does not take his hips off the mat, the elbows touch the knee and when returning to the starting position the exerciser touches the ground with the shoulder blades. Do as many repetitions as possible in 2 minutes. During the bends, the strength and endurance of the abdominal muscles are assessed.

- Shuttle run

The shuttle run is performed over a distance of 10 by 10 meters. At the signal, the trainee starts running towards the cone, runs around it and returns to the starting cone, which he also runs around, thus starting the

second lap. Such a route is performed five times on time and after each lap the evaluator informs about the number of repetitions. In the shuttle run, the speed and agility of the exerciser are assessed.

- Beep test

The beep test is an endurance test that involves running between two markers 20 meters apart. The pace is given by a sound signal and the exerciser's task is to run the section within the given time. If the exerciser reaches the marker before the signal, he waits for it before moving on. With each level reached, the signal accelerates and the practitioner must fit within the designated time interval. In the case of not fitting between the signals twice, the trainee drops out of the test.

- Barbell press lying on a straight bench

The exercise consists in squeezing as much load as possible while lying on a straight bench. Before performing the final test, the trainee performs several preliminary series in order to prepare the muscles for the maximum load. The exercise is performed with the arms apart at the width of the shoulder girdle and the lower limbs are to be in constant contact with the ground. The attempt is passed when the exerciser touches the barbell to the chest and presses the weight above himself to almost maximum extension in the elbow joint. The test is performed in the belaying of two people. In the barbell press, the strength of the shoulder and chest muscles is assessed.

Results

Table 1. Characteristics of the first military class body composition components

	Class I			
Somatic features and components of body composition	**Mean**	**Minimum**	**Maximum**	**Standard deviation**
body height (cm)	177.5	172	184	3.50
body weight (kg)	68.7	54	80.4	9.33
fat (%)	12.4	4.2	22.6	5.91
fat mass (kg)	9.0	2.4	18.2	5.22
fat free mass (FFM) (kg)	59.6	51.2	65.4	4.82
muscle mass (kg)	56.8	48.4	62.6	4.82
body mass index (BMI)	21.7	18.3	26.6	2.61

The conducted analysis of the components of the body composition of the first military class showed the level of body fat. The average Fat % value was 12.4%, the minimum value was 4.2% and the maximum was 22.6%. The deviation of body fat from the mean was 9.33. In the study group, the weight of fat ranged from 2.4 kg to 18.2 kg and the average value was 9 kg. Military-class lean body mass averaged 59.6 kg, with a minimum of 51.2 kg and a maximum of 65.4 kg. The population standard deviation in FFM was 4.82. The average muscle mass index was 56.8 kg, its minimum value was 48.4 kg and its maximum value was 62.6 kg. On the basis of body weight and height, BMI was calculated, the average value of which was 21.7, the minimum value was 18.3, the maximum value was 26.6, and the deviation from the average BMI was 2.61.

Table 2. Characteristics of the components of the body composition of the IV military class

Class IV				
Somatic features and components of body composition	**Mean**	**Minimum**	**Maximum**	**Standard deviation**
body height (cm)	183.1	173	193	6.03
body weight (kg)	82.5	68.8	101	9.14
fat (%)	16.9	8.2	24.7	4.44
fat mass (kg)	14.3	5.6	24.9	5.17
fat free mass FFM (kg)	68.2	61.3	76.1	4.55
muscle mass (kg)	65.4	58.5	73.3	4.55
body mass index BMI	24.6	21.5	27.2	1.84

Among the students of the fourth military class, the average level of body fat was 16.9%, its minimum value was 8.2% and the maximum was 24.7%. The deviation from the mean body fat value was 4.44. In the study group, the mass of fat oscillated from 5.6 kg to 24.9 kg, and its average value was 14.3 kg. The average lean body mass of the respondents was 68.2 kg, minimum 61.3 kg and maximum 76.1 kg. The deviation of this value from the mean was 4.55. The muscle mass of the study group ranged from 58.5 kg to 73.3 kg and its average value reached 65.4 kg. On the basis of body weight and height, BMI was calculated, the average value of which was 24.6, the minimum value was 21.5, the maximum value was 27.2, and the deviation from the average BMI was 1.84.

Table 3. Table of points for the shuttle run from the physical fitness test of professional soldiers (Journal of Laws of the Republic of Poland, Warsaw, December 22, 2020, item 2331, Regulation of the Minister of National Defense)

Time	Points	Time	Points
28.6	19.0	31.2	10.2
28.7	19.0	31.3	9.8
28.8	19.0	31.4	9.4
28.9	19.0	31.5	9.0
29.0	19.0	31.6	8.6
29.1	18.6	31.7	8.2
29.2	18.2	31.8	7.8
29.3	17.8	31.9	7.4
29.4	17.4	32.0	7.0
29.5	17.0	32.1	6.6
29.6	16.6	32.2	6.2
29.7	16.2	32.3	5.8
29.8	15.8	32.4	5.4
29.9	15.4	32.5	5.0
30.0	15.0	32.6	4.6
30.1	14.6	32.7	4.2
30.2	14.2	32.8	3.8
30.3	13.8	32.9	3.4
30.4	13.4	33.0	3.0
30.5	13.0	33.1	2.6
30.6	12.6	33.2	2.2
30.7	12.2	33.3	1.8
30.8	11.8	33.4	1.4
30.9	11.4	33.5	1.0
31.0	11.0	33.6	0.6
31.1	10.6	33.7	0.2

Table 4. Table of pull-ups from the physical fitness test of professional soldiers (Journal of Laws of the Republic of Poland, Warsaw, December 22, 2020, item 2331, Regulation of the Minister of National Defense)

Repeat	Points
18	21.0
17	21.0
16	21.0
15	21.0
14	20.2
13	19.4
12	18.6
11	17.8
10	17.0
9	16.2
8	15.4
7	14.6
6	13.8
5	13.0
4	12.2
3	11.4
2	10.6
1	9.8

Table 5. Table of torso tilts from the physical fitness test of professional soldiers (Journal of Laws of the Republic of Poland, Warsaw, December 22, 2020, item 2331, Regulation of the Minister of National Defense)

Repeat	Points	Repeat	Points
70	16.0	49	11.8
69	15.8	48	11.6
68	15.6	47	11.4
67	15.4	46	11.2
66	15.2	45	11.0
65	15.0	44	10.8
64	14.8	43	10.6
63	14.6	42	10.4
62	14.4	41	10.2
61	14.2	40	10.0
60	14.0	39	9.8
59	13.8	38	9.6
58	13.6	37	9.4
57	13.4	36	9.2
56	13.2	35	9.0
55	13.0	34	8.8
54	12.8	33	8.6
53	12.6	32	8.4
52	12.4	31	8.2
51	12.2	30	8.0
50	12.0		

Table 6. Classification of the first class students' points from the physical fitness test of professional soldiers

	Mean	Minimum	Maximum	Standard deviation
pull-ups	15.0	9.8	21.0	3.62
torso bends	13.5	11.4	15.4	1.19
shuttle run	12.6	2.6	19.0	5.70

Based on the scores from the physical fitness test of professional soldiers, it was possible to determine the number of points from fitness tests obtained in the first military class. The average number of points scored in the pull-up test was 15, the minimum was 9.8 and the maximum was 21. The deviation from the average was 3.62. In the timed trunk bending test, the average number of points obtained by the subjects reached the value of 13.5, the minimum 11.4, the maximum 15.4, and the population standard deviation was 1.19. Respondents in the shuttle run received from 2.6 to 19 points and the average was 12.6 points. The deviation from the mean in this sample was 5.70.

Table 7. Classification of the fourth class students' points from the physical fitness test of professional soldiers

	Mean	Minimum	Maximum	Standard deviation
pull-ups	13.9	11.4	21.0	3.20
torso bends	13.4	10.8	15.4	1.36
shuttle run	9.9	0.0	19.0	6.93

The respondents in the pull-up test scored from 11.4 to 21 points, with an average of 13.9 points. Deviation from the average in pull-ups is 3.20. The average number of points obtained in trunk slopes reached 13.4, the minimum 10.8, the maximum 15.4 and the population standard deviation 1.36. The test group in the shuttle run received an average of 9.9 points. Their minimum value was 0 and the maximum was 19. The deviation from the mean in this sample was 6.93.

Table 8. The first military class students' fitness test results

Test type	Mean	Minimum	Maximum	Standard deviation
pulling up on the bar	7.5	1.0	16.0	4.68
beep test	1040.0	500.0	1500.0	326.19
torso bends	57.7	47.0	67.0	5.97
shuttle run	30.5	28.1	33.1	1.54
barbell press	75.3	62.0	88.0	7.90

The average number of pull-ups on the high bar in the first military class was 7.5, the weakest attempt was 1 repetition and the best 16. The deviation from the average was 4.68. The tested group in the beep test achieved results from 500 meters to 1500 meters. The average value in the fitness test was 1040 meters and the standard deviation of the group was 326.19. In the forward bend test, the respondents achieved an average score of 57.7 repetitions. The minimum value of this test is 47 slopes, while the maximum is 67. A group of military first- class students in the shuttle run achieved results from 28.1 to 33.1 seconds. The average value of the group in this run was 30.5 seconds, while the standard deviation from the mean was 1.54. During the barbell press on a straight

bench, the subjects achieved results from 62 kg to 88 kg. The average bench press value in the first class was 75.3 kg and the deviation from the mean was 7.90.

Table 9. The fourth military class students' fitness tests results

Test type	Mean	Minimum	Maximum	Standard deviation
pulling up on the bar	6.2	3.0	15.0	4.00
beep test	1015.0	520.0	1540.0	304.32
torso bends	57.1	44.0	67.0	6.84
shuttle run	31.3	28.0	34.4	1.95
barbell press	93.3	78.0	120.0	12.30

In the test for the maximum number of pull-ups on the high bar, the average value of the subjects was 6.2 repetitions, the smallest 3 and the largest 15. The deviation from the average was 4. During the beep test, the results oscillated from 520m to 1540m. The average value of the uniformed group in this test was 1015m and the deviation was 304.32. The forward bends ranged from 44 to 67 repetitions and their average value was 57.1. The shuttle run in the fourth military class averaged 31.3 seconds, the fastest time was 28 seconds and the worst time was 34.4 seconds. During the barbell press on a straight bench, the subjects achieved results from 78 kg to 120 kg. The average bench press value was 93.3 kg and the deviation from the average was 12.30.

In order to find out whether body composition affects the results obtained from fitness tests, Pearson correlations were performed with all data.

Table 10. The value of the correlation coefficient and interpretation

Correlation coefficient value	The strength of the relationship
below 0.2	poor (no relationship)
0.2–0.4	short
0.4–0.6	moderate
0.6–0.8	high
0.8–0.9	very high
0.9–1.0	full dependency

Table 11. The influence of body weight on the results obtained in fitness tests

	Pull-ups	beep test	Torso bends	Shuttle run	Barbell press
class I	–0.57	–0.75	–0.80	0.65	0.93
class IV	–0.60	–0.37	–0.84	0.87	0.86

The results of the Pearson correlation show that the greater the weight of the subject's body, the worse the result in the high bar pull-up test. The correlation in this case obtained a moderate value in both military classes. During the beep test, the correlation in the first class is high and in the fourth class – low. Negative correlation means that the greater the body mass of the examined person, the worse the result in the sample obtained. During the shuttle run in the first class a high correlation was obtained and in the fourth class correlation between both variables was very high. In the test for trunk bends, very high correlations between the number of repetitions and

body weight were obtained in both classess. During the barbell bench press, a correlation was obtained, which means a full relationship between the body weight and the obtained result, i.e. the greater the body weight of the tested person, the better the result in the straight bench press.

Table 12. The influence of the level of body fat on the results of fitness tests

	Pull-ups	beep test	Torso bends	Shuttle run	Barbell press
class I	–0.65	–0.85	–0.91	0.80	0.82
class IV	–0.85	–0.67	–0.87	0.90	0.71

When trying to pull up on a high bar, a negative correlation was obtained in both cases, which means that the higher the level of body fat, the worse the result in the number of pull-ups. In the first class the correlation is high, while in the fourth class it is very high. In the beep test, the correlation between Fat % and the distance run is negative, very high in the first class and high in the fourth class. The strength of the relationship between adipose tissue and trunk slopes is very strong in the fourth class, while in the first class a full relationship was obtained between both variables. The results in the shuttle run in both cases mean that the correlation between Fat % and the obtained result is very high, i.e. the more body fat, the longer the time during the run. Bench press on a straight bench in the first class had a high relationship strength and in the fourth class it was very high.

Table 13. The influence of lean body mass on the results of fitness tests

	Pull-ups	beep test	Forward bends	Shuttle run	Barbell press
class I	–0.41	–0.52	–0.57	0.38	0.90
class IV	–0.34	–0.09	–0.69	0.71	0.81

The strength of the relationship between the number of repetitions achieved in pull-ups and lean body mass is negative, moderate in the first class and low in the fourth military class. During the beep test, the correlation is moderate at the beginning of education and weak, i.e. no connection in the last class. The test for the number of forward bends showed moderate strength in the first class and high strength in the fourth class. During the shuttle run, a low correlation was obtained in the first class and high in the fourth class between lean body mass and time obtained in the run. The barbell bench press in both cases obtained a very high strength of the relationship between the two variables.

Table 14. The influence of body fat mass on the results of fitness tests

	Pull-ups	beep test	Torso bends	Shuttle run	Barbell press
class I	–0.64	–0.86	–0.90	0.81	0.82
class IV	–0.76	–0.58	–0.88	0.92	0.80

The strength of the correlation in the pull-up test is negative and high in both groups, i.e. greater body fat mass will negatively affect the number of repetitions. In the beep test, the correlation is very high in the first class and moderate in the fourth class. During trunk bends, you can see a very high relationship between the number of repetitions achieved and body fat mass in both cases. In the shuttle run, the correlation is positive in both cases,

very high in the first class and in the fourth class there is a full dependence between the variables examined. In the barbell bench press test, the strength of the relationship is positive, and there is a very high relationship between the mass of adipose tissue and the maximum weight obtained in the test.

Table 15. The influence of muscle mass on the results of fitness tests

	Pull-ups	beep test	Torso bends	Shuttle run	Barbell press
class I	–0.41	–0.52	–0.57	0.38	0.90
class IV	–0.34	–0.09	–0.69	0.71	0.81

During the pull-up attempt, there was a moderate negative correlation in the first class and a low correlation in the fourth class between the number of repetitions and the muscle mass of the students. In the capacity test, the strength of the compound in the first class is moderate, while in the fourth class it is weak. The number of repetitions in trunk bends and the muscle mass of the study group had a moderate effect on the result in the first class, and a high one in the fourth class. In the shuttle run, the correlation is positive in both cases, low in class I and high in class IV. The barbell bench press in both cases obtained a very high strength of the relationship between the two variables.

Table 16. Influence of BMI on the results of fitness tests

	pull-ups	beep test	Torso bends	Shuttle run	Barbell press
class I	–0.53	–0.80	–0.85	0.70	0.84
class IV	–0.68	–0.42	–0.71	0.85	0.75

The strength of the relationship between the pull-up test and BMI is negative, moderate in the first class and high in the fourth class. During the beep test, the correlation in the first group is very high and in the second group it is moderate. The number of repetitions in trunk bends and BMI in the study group has a very high relationship strength in the first class and high in the fourth class. In the shuttle run, both groups present a positive correlation with a high and very high relationship between the two variables. Pressing the barbell on a straight bench in both cases has a positive correlation, in the first class the strength of the relationship is very high, while in the fourth class it is high.

Discussion

Physical fitness is a key factor that determines a healthy lifestyle. The term is understood in many ways, but these definitions share one common goal, which is to be fit. Physical fitness plays a particularly important role in military classes in high school. The task of classes with a military profile in Polish schools is to prepare young people for future service in various uniformed services, such as the army, police, fire brigades or other special services. When working in such professions, fitness is a factor that can save human lives, which is why performing fitness tests and constantly developing physical activity is a mandatory element. Examination of physical fitness has been conducted with the aid of the “physical fitness test of professional soldiers” used by the Polish Army, from which there were used 3 tests: pull-ups on a high bar, swing run and forward bends. In addition to the above-mentioned tests, the test included the “Beep test” and the barbell bench press. These studies helped to capture the

relationship between body composition and the level of selected motor skills, showed differences between the first and last military class and assessed the level of fitness of the surveyed military classes When analyzing the body weight of the surveyed military classes, it is possible to notice the differences between the first and fourth military class. The average body weight of the subjects from the first class was 68.7 kilograms, while in the fourth class this value was 82.5 kg. This means that the difference between the two groups was less than 14 kilograms. As for the minimum and maximum values in both classes, the younger respondents reach a body weight of 54.0 to 80.4 kilograms, while the older respondents range from 68.8 to 101 kilograms. Cameron and Jason studied the physical fitness of the United States Air Force, during which they examined the body weight of soldiers. Their average value was 74.9 kilograms, the difference between the maximum and minimum body weight reached the result of 15 kg. Comparing the research results of authors from the United States with students of uniformed groups in Leżajsk, it should be stated that the average body weight of first-class students is lower, and higher in fourth-class students than US Air Force soldiers (Mackey & DeFreitas, 2019). Analyzing the results obtained with bioelectrical impedance, we can see differences in body composition components between first and fourth military class. The percentage of body fat at the beginning of education in the military classes ranged from 4.2% to 22.6% and its average was 12.4%, while in the last class it ranged from 8.2% to 24.7% with the average 16.9%. The average value of both groups was at the correct level and is within the standards for Fat % according to the World Health Organization. Considering the results of the research group, we can see that the level of body fat is higher in the last uniformed class. We can see the same relationship when analyzing other components of body composition. The average weight of fat in the first class is 9 kg and is 5 kg less than in the fourth class. If we take into account the lean body mass (FFM), the difference in the average is 9 kg in favor of the younger group of respondents. Comparing the muscle mass of the studied groups, we notice a difference in favor of the older uniformed class. The average muscle mass is 56.8 kg in the first class, while in the fourth class it is 65.4 kg and differs by 8.6 kg. Comparing the components of body composition from the uniformed groups in Leżajsk, research on military units of the Spanish Armed Forces should be shown. Bustamante-Sánchez and Clemente-Suárez (2020) studied 179 male aircrew members. The study consisted in comparing the body composition between soldiers piloting planes and soldiers who belonged to the crews of transport planes. The average body fat level of the pilots was 16.8% and that of the crew was 23.7%. As for the other components, the lean mass ranged from 58.7 to 63.95 kg in the case of the second group, and the difference between the muscle mass was almost 3 kg in favor of the pilots (Bustamante-Sánchez & Clemente-Suárez, 2020). The result of the pilots' body fat level is almost identical to the Fat % of students from the fourth uniformed class in the Secondary School, which was 16.9% and differed only by 0.1%. Thanks to electrical bioimpedance, the BMI values in both classes were examined. The average BMI value in the first military classes was 21.7 and in the fourth class it was 24.6. Both obtained results, despite the difference of 3.9 points, mean that the body weight of the subjects is correct in relation to body height. Mitchell et al.(2008) studied the body composition of US military medical students. The University of Uniformed Services requires that students present a high level of physical fitness and lead a healthy lifestyle with the principles of proper nutrition. At this college, all students are on active military service and are required to maintain a minimum level of fitness within specified military standards. 163 military medicine students in the last class were examined. Studies have shown that BMI increased by 5 percentage points between the first and last year of study. The average BMI value was 24.2 and remained within the standards required by the University of Uniformed Services (Mitchell et al., 2008). Comparing the results of American military students to students of military classes in Leżajsk, it should be noted that the body mass index BMI does

not differ significantly, because it is a difference of only 0.4%. The analysis of the results in the pull-up strength test showed that first-year students achieved better results than the military from the fourth class. The average of younger students' pull-ups was 7.5 repetitions, while in the case of their older peers this value was 6.2. Tomczak (2017) examined a group of Riflemen of the Rifle Unit 1313, in which 32 men took part. According to the author, the most important motor ability of a soldier, after endurance, should be the strength of the shoulder and back muscles. During the pull-up test, shooters performed an average of 4.39 repetitions (Tomczak & Klasa, 2017). Despite less experience in the army, students of uniformed groups in Leżajsk fared much better than the Riflemen of the Rifle Unit 1313. During abdominal bends, first-class students performed an average of 57.7 repetitions in two minutes, and fourth-class students performed 57.1 repetitions. These results are practically identical, so it can be concluded that the strength of the abdominal muscles in both classes is on the same level. The results of trunk bends of the "Shooters" in the study by Tomczak (2017) are worse than those of students from the High School, because their average is 52.2 (Asienkiewicz & Kwapisz, 2015). Asienkiewicz and Kwapisz (2015) conducted research on professional soldiers from the sapper battalion. The average number of repetitions in trunk bends at the age of up to 25 years was 57.7 (Fransson, 2020). Taking into account the results from the 10 × 10 m shuttle run, it should be stated that the younger uniformed men achieved better times than the older ones. Their average result was 30.5 seconds, while in the second group it was 31.3 seconds. A group of professional soldiers from the sapper battalion achieved a better result than the uniformed groups from Leżajsk, because their average was only 29.41 s (Fransson, 2020). Comparing these results, it should be stated that the group of sappers is characterized by better speed and agility abilities. The situation is different if we compare these results to the group of Riflemen of the Strzelecka Unit 1313. Their average during the shuttle run was 34.7 s, which is a much worse result than the military class from high school (Asienkiewicz & Kwapisz, 2015). During the endurance and oxygen test, the military classes from Leżajsk presented themselves worse than the studies of other authors. The average result in the first class was 1040 meters and in the fourth class 1015 meters. The differences are minimal, therefore, it should be stated that both groups present the same aerobic capacity during the beep test. Fransson (2020) studied a group of male recruits in the Swedish Armed Forces for aerobic fitness. During the beep test, the recruits obtained an average score of 10.8, which is equal to 1820 meters (Conkright, et al., 2020). Another author studied US soldiers from a US Army unit Ranger. In the beep test, the soldiers achieved an average result of 1680 meters (Conkright et al., 2020). Taking into account the results of research on a group of soldiers from different parts of the world, it should be stated that a group of students from the military class in Leżajsk should improve their performance capabilities, because they differ significantly in the average results. The correlation between body composition components and fitness tests in both military classes showed that higher body mass index, body fat, FFM, muscle mass and BMI had a negative impact on all the results in the performed tests, except for the barbell bench press. The level of body fat, body fat mass, body mass and BMI index influenced the most the results in the pull-up test, aerobic capacity, abdominal muscle strength and in the shuttle run. Higher body mass, lean body mass and muscle mass, however, are fully related to strength during the straight bench press. This means that the strength of the shoulder and chest muscles increases along with the components mentioned above. When it comes to comparing the two groups against each other, the first class performs better during pull-ups on the bar and in the shuttle run. The fourth class, on the other hand, achieved better results in the barbell press on a horizontal bench. Abdominal muscle strength and aerobic capacity during the beep test are similar in both study groups. Studies of special forces soldiers of the United States Army showed that lower levels of body fat and fat mass had a positive effect on the results in all tests (Mitchell et al.,

2008). Mendoza-Muñoz et al. (2020) investigated the influence of body mass components on the physical fitness of students. Body weight, BMI, body fat mass, Fat % and FFM were measured. It has been shown that a correct body weight contributes to obtaining better results in speed and agility tests. The results showed that a higher level of body fat, BMI and body fat mass negatively affected the performance test. There was also a direct relationship between speed and agility and body fat mass. The author's conclusions coincide with the results obtained during the study of uniformed groups from Leżajsk (Asienkiewicz & Kwapisz, 2015).

In conclusion, it should be stated that body composition components affect the results obtained during fitness tests. The surveyed military classes had no difficulties in performing fitness tests and their results do not differ from the values obtained in other regions of the world. Systematic physical activity related to the specificity of the military profile at the Secondary School in Leżajsk positively affects the body composition of uniformed groups.

Conclusions

The analysis of body composition components, physical fitness tests for speed, agility, endurance and strength, as well as the correlation between body composition and the results of fitness tests, implies the following conclusions:

- Bioimpedance showed higher values in all components of body composition among students of the fourth military class. These differences result from the specific nature of military profile classes. During the four-year education, students have contact with many specialist classes on which they build their physical fitness and the use of a high-calorie diet provides them with the necessary energy.
- The correlation between body composition and fitness tests showed that higher levels of body fat, lean body mass, BMI and body weight negatively affect the results obtained in pull-ups, trunk bends, shuttle runs and beep tests. Greater body weight, lean body mass and muscle mass positively affect the results of the barbell bench press. Maintaining a balanced diet and high physical activity will positively affect the balance between body composition and physical fitness of uniformed personnel.
- Differences in the results between the first and last military class were shown. The group of younger uniformed officers performs better during pull-ups on the bar and in the shuttle run, and the fourth class in the barbell bench press test. The forward bends of the torso and the results obtained in the beep test are at a similar level. Gaining muscle mass and strength exercises will positively affect the results of the barbell bench press in the group of first-class students. Older uniformed officers, on the other hand, should perform more exercises developing the strength of the shoulder girdle muscles.

List of acronyms

- BIA – Bioelectrical Impedance Analysis
- BMI – Body Mass Index
- FFM – Fat Free Mass
- FM – Fat Mass
- MM – Muscle Mass

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KINEMATIC DIFFERENCES IN THE ROUNDHOUSE KICK AMONG UNIVERSITY TAEKWONDO PLAYERS: BRIEF REPORT

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Abstract This study aimed to investigate the bilateral kinematic differences in temporal variables between the dominant and non-dominant legs in the roundhouse kick of college-level women practicing Taekwondo. Four male athletes with black belts volunteered to participate in the study. Participants were instructed to perform five kicks with each leg after visual stimuli at maximal velocity allowing 30-s passive recovery time between each kick. Reaction time, movement time, and attack time in the roundhouse kick were assessed using video cameras and force platforms for both the dominant and non-dominant legs.

The analysis revealed no significant differences in reaction times (0.15 ±0.03 and 0.15 ±0.04 s, n = 20), movement times (0.62 ±0.06 and 0.64 ±0.04 s, n = 20), or attack times (0.77 ±0.09 and 0.79 ±0.06 s, n = 20) for the dominant and non-dominant legs ($p > 0.05$). However, a bilateral dominance was observed, consistent with the sporting level of the participants. These results support an equally oriented training regimen focusing on both the left and right kicking legs to enhance overall performance in Taekwondo.

Key words: sports biomechanics, medium roundhouse kick, college athletes, taekwondo, kinematics

Introduction

Taekwondo (TKD) is a Korean-origin martial art that has been considered an Olympic sport since 2000 (De Prado et al., 2011). What distinguishes TKD from other combat sports is that even though its name can be translated as the art of punching and kicking, it presents a predominant use of the legs over the arms (Park et al., 2009; Rufino Añorbe, 2017), whereas the medium roundhouse kick is not only one of the most widely implemented movements in the discipline but also one of those that can generate greater strength and speed (Falco et al., 2013; Pieter & Pieter, 1995).

Due TKD it is a combat sport, numerous studies focus on recognizing the factors that intervene or influence sports technique, where biomechanics has made interesting contributions to improve sports performance (De la Fuente & Gómez-Landero Rodríguez, 2019; Falco et al., 2013). Comparisons by sporting levels have made it possible to recognize the kinematic and neuromuscular variables that describes the elite TKD athletes from non-elite ones, the latter presenting a longer time to initiate the movement, although both groups are the same regarding the EMG of the knee extensors (Ervilha et al., 2020).

Other reports on TKD compare athletes of different competitive levels in physical and physiological profiles (Moreira et al., 2016) focusing mainly on the effect of impact (Estevan & Falco, 2013; Quinzi et al., 2013; Thibordee & Prasartwuth, 2014). In this sense, the use of the dominant (D) and non-dominant (ND) leg is a controversial issue in sports medicine (Falco et al., 2013), in the practice of TKD the use of a particular leg is usual during training, however, reaching the elite level requires symmetrical skills on both legs (Tang et al., 2007) as well as quick reaction time for greater success in competitions (Junior et al., 2020; Vieten et al., 2007).

These demands have been analyzed in a wide variety of studies (Yilmaz, 2023). In terms of reaction speed in TKD, comparisons between medalists vs. non-medalists are targeted, specifically addressing motor differences in TKD cadet athletes according to a competitive level and competitors vs. non-competitors (Falco, et al., 2009; Vieten et al., 2007) reporting that a lower reaction speed is characteristic of competitors of a higher sporting level.

The Roundhouse Kick (RHK) is a motor gesture that has been studied considering bilateral comparisons in elite black belt athletes. Competitive athletes have reported no differences in impact force and temporal reaction variables between their D and ND legs, regardless of the target distance (Falco, et al., 2009; Tang et al., 2007). Likewise, medalists athletes showed greater impact force and shorter execution time than non-medalists (Estevan et al., 2013).

When the participants are induced to fatigue reaction time increases as well as kick impact decreases (Sant'Ana et al., 2017). To the best of our knowledge, research has primarily concentrated on investigating performance variables in elite athletes, with limited attention paid to undergraduate performance. Furthermore,

much of the available data has been collected in developed countries such as Korea, Japan, the USA, or the UK. However, there is a significant gap in information regarding this topic in Latin America. Therefore, the present study is designed to address this gap and aims to assess bilateral kinematic variations in temporal variables during the execution of the mean roundhouse kick in college-level women practicing Taekwondo in Mexico.

Material and Methods

Participants

Four female Black Belt taekwondo athletes (age: 23.5 ±2.9 years, weight: 63.0 ±12.9 kg, height: 161.0 ±5.5 cm, experience: 10.8 ±3.2 years) voluntarily participated in the study and provided informed consent in accordance with the Helsinki Declaration. Their training regimen included at least three two-hour sessions per week, with two of them being non-competitive at the time of the study. The study was approved by the by committee scientific board of the Autonomous University of Chihuahua with registration code 210923-064.

Table 1. General characteristics of the participants

Subject	Age (Years)	Weight (kg)	Height (cm)	Experience (Years)
1	27	80	164	8
2	23	57	155	14
3	24	50	158	13
4	20	65	167	8
Mean	23.5	63.0	161.0	10.8
±SD	2.9	12.9	5.5	3.2

The circular roundhouse kick test was executed by the participant and captured using a setup comprising 12 active cameras (Vicon®), operating at a sampling frequency of 100 Hz and included 39 reflective passive markers with a diameter of 12 mm were placed on bone anatomical landmarks of the body proposed by Vicon®.

An additional video camera (Basler model a2A1920-51gmBAS) with a sampling frequency of 50 Hz was used to synchronize the visual stimulus and calculate the reaction time. This camera was employed to ascertain the duration during which the light source was active. Following this interval, the activation of movement time was initiated and consistently identified until alterations were discerned by the force platform. The participant was questioned as to their preferred leg to discriminate their dominant and non-dominant leg.

The test involved executing five repeated medium roundhouse kicks using both the dominant and non-dominant kicking legs, with a 30-second rest between each kick. Participants were instructed to execute the kick as quickly as possible after observing the visual stimulus (a light) and aiming to hit the palchagui target and return to the starting position (as shown in Figure 1).

The study recorded changes in Ground Reaction Force (GRF) using two force platforms (AMTI) connected analogically at a sampling frequency of 1000 Hz. The data were processed using Nexus 2.5 software. Prior to the test, the subjects underwent anthropometric measurements necessary for data analysis, including body mass and height measured using a digital scale and stadiometer (Tanita WB 3000). The visual stimulus was determined using a red LED light, and the target was to hit a palchagui.

The trochanter-ankle length allows the height of the hitting palchagui and is then adjusted by the subject.

Experimental procedure

Each subject underwent a joint warm-up and a period of kicking the palchagui, accumulating a total of 10 minutes. Once the warm-up was complete, the legs were placed on the force platforms, with the palchagui and visual stimulation located in front at a comfortable distance for the subject.

The test consisted of executing five repeated medium roundhouse kick with the left and right legs; a 30-second rest was given between each kick. After observing the visual stimulus getting on, the kick should be executed as quickly as possible, aiming to hit the palchagui and return to the starting position (Figure 1).



Figure 1. The sequence of the roundhouse kick

The variables recorded in this study were:

i) Reaction time (RT): This refers to the time that elapses once the light of the visual stimulus is turned on and the moment in which the force plate registers contact changes in the attacking leg.
ii) Movement time (MT): This is the time immediately after the RT until the attacking leg contacts the palchagui. This was measured trough motion analysis.
iii) Attack time (AT): This is the sum of RT and MT, representing the total time taken to execute the kick from the moment the visual stimulus is presented.

Statistical analysis

Statistical analysis involved Wilcoxon test to compare between the two legs (D and ND). For intra-subject comparisons, an ANOVA of one factor with post hoc and Bonferroni corrections was used, with a significance level of 0.05. The outcomes of the statistical analysis were employed to identify significant differences among the measured variables, including reaction time, movement time, and attack time, utilizing the Statistical Package for the Social Sciences version 15.0.

Results

Figure 2 shows no significant differences found between the dominant (D) and non-dominant (ND) leg in terms of mean times for each phase of RT (0.15 ±0.03 and 0.15 ±0.4 s, n = 20), MT (0.62 ±0.06 and 0.64 ±0.04 s, n = 20) and AT (0.77 ±0.09 and 0.79 ±0.06 s, n = 20) respectively for D and ND leg.

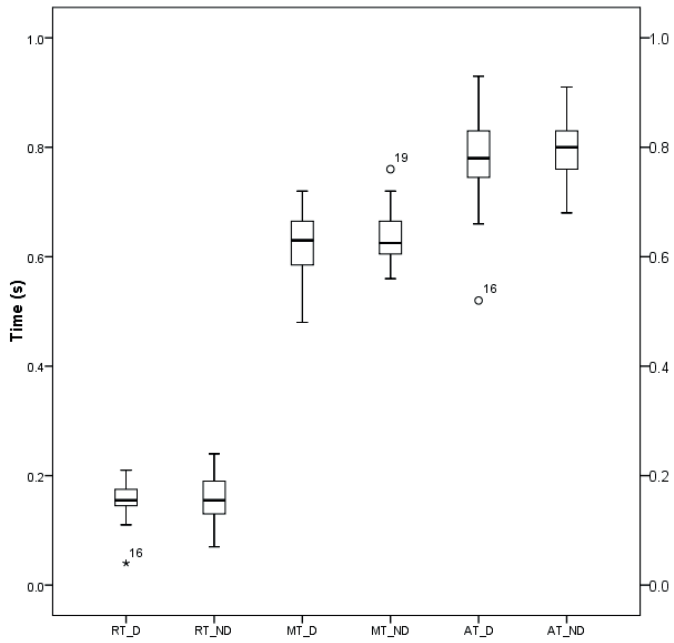


Figure 2. Mean values for times in the dominant (D) and non-dominant (ND) leg in reaction (RT), movement (MT) and attack (AT)

Table 2 shows mean and SD for reaction time (RT), movement time (MT) and attack time (AT) for both kicking legs. Intrasubject comparison confirms that participant 4 has the lower time for most of kicking variables within bilateral components.

Table 2. Within-subject comparisons for the variables reaction time (RT), movement time (MT), and attack time (AT) between the dominant leg (D) and the non-dominant leg (ND)

Variable	Leg	Subject	Number of attempts	Mean (s)	Standard deviation
RT	Dominant	1.00	5	0.17	0.02
		2.00	5	0.14	0.02
		3.00	5	0.18	0.03
		4.00	5	0.14	0.06
		Total	20	0.16	0.04
MT	Dominant	1.00	5	0.64	0.03
		2.00	5	0.64	0.02
		3.00	5	0.68	0.04
		4.00	5	0.52*	0.03
		Total	20	0.62	0.07
AT	Dominant	1.00	5	0.81	0.05
		2.00	5	0.78	0.01
		3.00	5	0.85	0.06
		4.00	5	0.66*	0.08
		Total	20	0.78	0.09
RT	Non-Dominant	1.00	5	0.18	0.03
		2.00	5	0.18	0.04
		3.00	5	0.16	0.04
		4.00	5	0.10†	0.03
		Total	20	0.15	0.05
MT	Non-Dominant	1.00	5	0.60	0.02
		2.00	5	0.64	0.02
		3.00	5	0.69	0.03
		4.00	5	0.63	0.08
		Total	20	0.64	0.05
AT	Non-Dominant	1.00	5	0.78	0.03
		2.00	5	0.82	0.05
		3.00	5	0.85	0.04
		4.00	5	0.73ⱪ	0.06
		Total	20	0.79	0.06

*Differences compared to the rest of the participants: † differences with participant 1 and 2; ⱪ differences with participants 2 and 3. Where: RT = reaction time; MT = movement time; AT = attack time.

Discussion

As expected for representative athletes at the university level and with a black belt category in TKD, they manage to maintain the same reaction times regardless of the dominant or non-dominant legs, which seems to be a common denominator in studies with subjects of that sports level. Developing the ability to hit in combat with both legs offers a perspective of symmetry. The same was reported by Kim and Kim (2010) mentioning that the reaction

times were similar for both legs, but they also evaluated other types of kicks such as front, side, back, thrashing, and turning-back kicks, with the same results in subjects with 10 years of experience in that sport.

On the other hand, Wąsik et al. (2018) and Andrzejewski and Elbaum (2005) found that the dominant leg had higher speed values, however their sample was made up of subjects with around five years of experience and the execution included targets of different sizes, as well as using the front kick. What it suggests is that by suggesting a test protocol with small objects (table tennis ball) subjects tend to focus their efforts on contacting the ball by stimulating specific areas of the brain involved in a manual response to peripheral visual stimulation that results in better times with the dominant leg. Another study also points out similarities in the dominant extremity and ND in kick speed, concluding that the participants present an inter-segmental coordination movement according to their elite sports level (Harun & Xiong, 2010).

The investigation into the bilateral symmetry of kicks has been explored by Yilmaz et al. (2021), their research delves into the examination of the preferred leg versus the non-preferred leg among TKD players. Remarkably, the study reveals an absence of discernible bilateral or ipsilateral strength ratios across various angular velocities. Nonetheless, the findings of the study also highlight significant inter-limb strength variations within individual legs, thereby adding nuance to our understanding of the intricate biomechanical aspects involved in executing kicks within the Taekwondo discipline.

Bilateral asymmetry, characterized by discernible differences between the dominant and non-dominant limbs, bears implications for combat sports as it may give rise to imbalances during engagements. While not inherently indicative of overall sports performance, it has been acknowledged as a contributing factor to the susceptibility of athletes to sports-related injuries (Lee et al., 2023). Recently (Harbili et al., 2022), noteworthy findings emerged, revealing an absence of significant strength distinctions between the dominant and non-dominant legs among TKD participants. The disparities in bilateral performance domain may be attributed to multifaceted factors, encompassing sample-specific characteristics, nuances in measurement methodologies, the distinct demands of task-specific movements, and the potential influence of varied training interventions. This underscores the intricacies involved in comprehending the role of bilateral asymmetry in the context of Taekwondo, prompting a holistic consideration of diverse variables in research and practice.

On the other hand, it must also be considered that auditory stimuli may not represent the best scenario of ecological validity since it is not a task that is commonly used in training or competition, in these cases, the visual part is the greatest trigger to initiate the motor gesture of the kick as we used in this study (Ervilha et al., 2020).

In relation to movement time, which is the interval immediately following the RT until the leg contacts the target, no changes were detected due to laterality. A consistent bilateral performance was observed with both left and right kicking leg. In this parameter, there are few references or similar studies, one of them was performed in the Frontal kick, the authors report 50% less time in this variable than our study subjects since the action requires less commitment and displacement of body segments than the roundhouse kick used in this study (Tsai et al., 2005).

Whether the movement time of the roundhouse kick can vary depending on the distance of the kicking leg and the target. In this regard, Kong et al. (2000) conclude that the trailing leg will take significantly longer to reach the target, however, it produces greater velocity due to the rotational components of the hip and trunk, thus generating greater momentum. Although it has also been reported that the greatest impact force is found at short distances, the author attributes that it is due to the visual stimulus as a trigger for the start of the movement, which requires a longer response time over long distances (Falco et al., 2013).

Intrasubject comparisons reveal that subject 4 exhibited significantly better performance than their peers. This can be attributed to their impressive sports record, which has earned them national-level awards and even a prestigious Teporaca award at the state level for their exceptional athletic achievements. The findings of this study provide valuable information about the potential connection between their performance in this study and their remarkable accomplishments in the field of sports.

Applications

The findings of this study have practical applications as a guide for dosing training in Taekwondo (TKD). The study reinforces the proposal that bilateral symmetry in leg strength is indicative of high-level athletes. Furthermore, it has been associated with a decrease in sports-related injuries due to balanced utilization of both the dominant and non-dominant legs. Therefore, these results can be utilized to optimize training programs in TKD, ensuring a balanced development of leg strength and reducing the risk of injuries.

Limitation of the study

Firstly, the relatively small sample size (n=4) may constrain the generalizability of our results. Larger sample sizes would enhance the robustness and external validity of the study. Secondly, our study specifically evaluated the roundhouse kick, while this allowed for a detailed examination of a specific technique, it limits the extrapolation of our findings to the broader spectrum of Taekwondo movements. The diversity of techniques within Taekwondo warrants consideration for a comprehensive understanding of bilateral comparisons. Moreover, the controlled environment in which the assessments took place may introduce a level of artificiality. Real-world combat scenarios involve additional stressors such as competitive pressure and heightened stress levels, which could impact performance differently. Therefore, the ecological validity of our study in mirroring actual combat situations may be a point of consideration.

Conclusion

Similar values of Reaction Time (RT), Movement Time (MT), and Action Time (AT) were found regardless of the leg used, suggesting that it is attributable to training time and skill level observed in individuals with Black Belt rank. This also allows for a bilateral training guide where both stances are trained to enhance success in this sport. By emphasizing the training using left and right legs, athletes can improve their overall performance in Taekwondo.

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EFFECT OF SUPERVISED PHYSICAL EXERCISE ON OXIDATIVE STRESS IN CHILDREN WITH AUTISM

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Abstract Background: The etiology of autism spectrum disorders is not well known but oxidative stress has been suggested to play a pathological role. Purpose: The present study aimed to investigate the effects of supervised physical exercise on oxidative stress in children with autism. Methods: Thirty boys with autism (7 to 9 years old) voluntarily participated in this study. They were randomly divided into experimental and control groups. The experimental group performed a physical curriculum known as sports, play and active recreation for kids (SPARK) for 12 weeks (3 sessions of 45 minutes per week), while the control group was exempted to participate in the program. As the clinical parameters, the level of brain-derived neurotrophic factor (BDNF) and malondialdehyde (MDA) were measured before and after the intervention. Results: The results indicated that BDNF levels significantly increased (85.7 %) and MDA concentration significantly decreased (29.2%) in the experimental group ($p < 0.05$). Conclusions: In conclusion, the supervised physical exercise may result in less oxidative stress in children with autism.

Key words: exercise training, oxidative stress, BDNF, malondialdehyde, autism

Introduction

Autism is one of the most complex childhood psychiatric disorders whose effects usually continue through the life (Mirzavandi et al., 2023). Recently, Centers for Disease Control and Prevention (*Morbidity and Mortality Weekly Report)* reported that one in 36 (2.8%) 8-year-old children have been identified with autism spectrum disorders (ASD) (*Autism Prevalence Higher, According to Data from 11 ADDM Communities*, 2023).

ASD's etiology is complex, and it may be due to the interaction of genetic and environmental factors (Zhang et al., 2021). Clinical evidence suggests that immunological dysregulation, inflammation, oxidative stress, mitochondrial dysfunction, and excitotoxicity are key components in ASD pathogenesis (Liu et al., 2022; Shen et al., 2020). Many markers of oxidative stress, such as malondialdehyde (MDA) are elevated in children with ASD (Chauhan et al., 2004). MDA is an indicator of lipid peroxidation as it increases following liver damage. Besides, the expression of Brain Derived Neurotrophic Factor (BDNF) which has a crucial role in survival and differentiation of neuronal populations during development is usually changed in children with ASD. The increased oxidative stress markers have been observed to be correlated with ASD severity (Ghezzo et al., 2013).

A curriculum known as sports, play and active recreation for kids (SPARK) is a physical program for living better along with enjoyment. This program has been designed in a way that it includes guidelines from the National Association of Physical Education and Sports, a program which is flexible enough and increases the cooperation of participants (McKenzie et al., 2016). This motor program may be welcomed by children with autism because of its liveliness, freshness and variety of games. By our knowledge, no previous study has investigated the effects of SPARK program on oxidative stress in ASD. Therefore, this study aimed to investigate the effects of a supervised physical exercise program on oxidative stress in children with autism.

Methods

This research was carried out according to the ethical principles of the World Medical Association (Declaration of Helsinki, 1993) and was approved by the ethics committee of the Islamic Azad University, Tehran's Science and Research Branch (project identification code: 920000427, 4.11.1395).

Subjects

Thirty boys with autism ranging from 7–9 years old from Imam Hassan Mojtaba institute in Shiraz (the capital of Fars province of Iran) voluntarily took part in the present study. Participants were randomly divided into experimental (n = 15) and control (n = 15) groups. The criteria for entering the study included: lack of heart, respiratory or orthopedic infectious and epilepsy diseases, not being prohibited to do physical activities, not using any certain medications that may have positive or negative effects on the results of blood samples, and finally having parent or legal guardian's consent form to participate in the research protocol. A subject was excluded from the study if he was absent in 3 consecutive or 4 nonconsecutive training sessions. To prevent participants from being excluded, however, the program was set to be conducted between class times and a make-up session was considered if necessary.

Study design

The present study was a semi-quasi study with pre-test, post-test, and control group during which the effectiveness of SPARK program on oxidative stress in children with autism has been investigated. To perform the study, first the method of doing study and considered objectives were explained shortly to the parents through a letter and they were asked to sign the consent form if they are satisfied with their children's participation in the study. Then, all participants had pre-test blood sample. After that, the experimental group participated in the SPARK program for 12 weeks (3 sessions of 45 minutes each week). This program included 10 minutes of body warm up, 10 minutes of physical activities, 20 minutes of recreational and fun games followed by 5 minutes of cooldown activities. The control group didn't participate in such intervention and they had their normal life and daily routine activities.

Measurements

To measure MDA and brain-derived neurotrophic factor (BDNF), the blood samples were taken from children's forearm vein. The blood samples were taken 24 hours before the start of intervention program (pre-test) and 48 hours after the end of week 12 (post-test), to make sure that the immediate effects of the intervention are removed. Then, the samples were transferred to the lab and were centrifuged at 3000 rpm for 10 minutes to separate the serum from plasma. After the separation serum from plasma, MDA and BDNF were measured by ELISA method using a special kit (Eastbiofarm, China) with the accuracy of 0.01 ng/ml.

Statistical Analysis

The skewness and kurtosis were used to examine the normal distribution of data. ANCOVA test was used to determine if significant ($P < 0.05$) differences existed among the groups for MDA variable between before and after exercise training. Post-test was the dependent variable; group was the fixed factor and pre-test was the covariate. Due to the skewed nature of the BDNF levels, Mann-Whitney U test was used to determine if significant ($P < 0.05$) differences existed among the groups for this variable between before and after training. The relationship between changes of MDA and BDNF was determined using Spearman correlation test. Data was analyzed using SPSS 22.0 statistical software. The level of significance in all statistical analyses was set at $P < 0.05$.

Results

Anthropometric measurements related to the experimental and control groups are presented in Table 1.

Table 1. Anthropometric parameters of the participants in each group (mean ±SD)

Variables	Experimental group	Control group
Height (cm)	140.5 ±8.0	140 ±8.0
Weight (kg)	33.1 ±5.8	31.1 ±4.9
Body mass index (kg/m^2)	16.6 ±1.2	15.7 ±1.4

The data on MDA concentration of the experimental and control group is presented on Figure 1. The results indicated that MDA concentration decreased after 12 weeks physical exercise compared to the control group (29.2%).

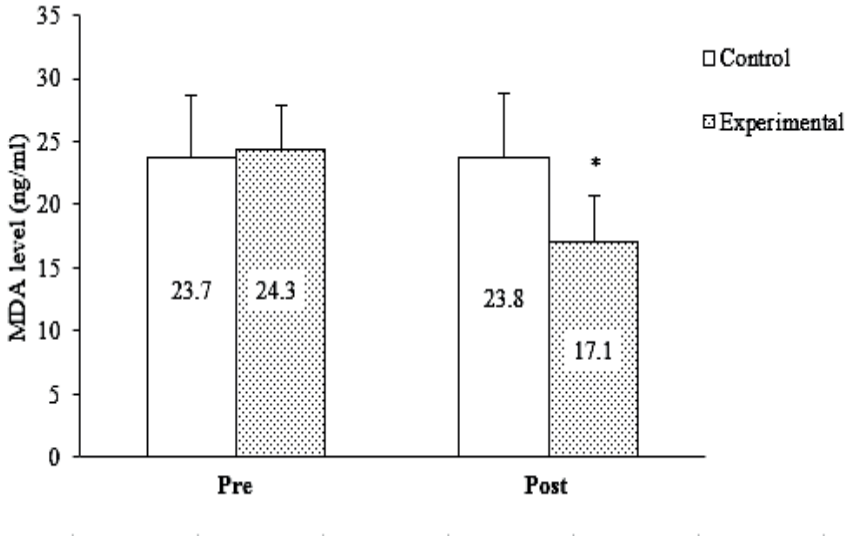


Figure 1. Changes of MDA in response to 12 weeks of supervised physical exercise. * Significant differences between group ($P < 0.05$)

The data on BDNF concentration of the experimental and control group is presented on Figure 2. The results on Mann-Whitney U test indicated that BDNF concentration increased in the experimental group compared to the control group ($Z = -3.5$; $p = 0.001$; 85.7%).

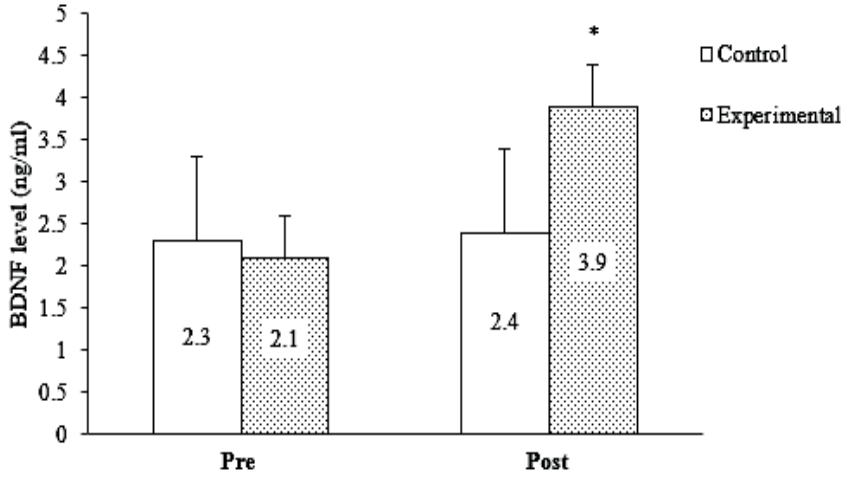


Figure 2. Changes of BDNF in response to 12 weeks of supervised physical exercise. * Significant differences between group ($P < 0.05$)

Spearman correlation demonstrated an inverse relationship between MDA levels and BDNF ($r = –0.73$, $P = 0.002$).

Discussion

The purpose of this study was to examine the effects of 12 weeks supervised physical exercise on oxidative stress in children with autism. The study results indicated that MDA concentration decreased after 12 weeks physical exercise compared to the control group. In line with the present study, recently, Mirzavandi et al. (2023) had been reported that moderate-intensity exercise training decreases MDA in rat model of autism (Mirzavandi et al., 2023). There is evidence that exercise training specifically promotes the upregulation of antioxidant defenses by elevating the activity of catalase (CAT) and total antioxidant capacity (TAC) (Sabet et al., 2022). Previous studies showed that regular exercise training decreased oxidative stress and promoted the upregulation of antioxidant factors by increasing the activity of superoxide dismutase (SOD), gluilktathione peroxidase (GPX) and CAT (Ennezat et al., 2001; Mirzavandi et al., 2023).

Autism is a neurodevelopmental disorder and BDNF plays an important role in neurodevelopment (Zaki et al., 2022). Recent studies have provided evidence to support the involvement of BDNF in autism through its neurotrophic effects on the developing brain (Han et al., 2022). Clinical studies indicated that BDNF levels are lower in the ASD cases than in the normal cases (Barbosa et al., 2020; Skogstrand et al., 2019). The BNDF concentration of plasma in normal people increases in the first few years after birth, and decreases slightly in adulthood. However, the opposite status is shown in ASD patients (Liu et al., 2020). Thus, it seems that due to their low expression in the early stages of development, ASD patients have a group of neurodevelopmental disorders.

The results of our research in confirmation of Al-Ayadhi's findings (Al-Ayadhi, 2012) showed that there is a direct relationship between BDNF and oxidative stress (MDA) in patients with autism. Thus, it seems that physical exercise training induced increase in BDNF concentration is responsible for MDA decreases in children with autism. In line with the present study, Zong et al. (2023) have reported that exercise training increases BDNF in ASD. Regulation of BDNF appears to be dependent on the calcium/calmodulin-dependent protein kinase II (CaMKII) signaling pathway and the cAMP response element-binding protein (CREB). Gomez-Pinilla et al. (2011) demonstrated that 3 months of exercise training increased BDNF gene expression within the hippocampus and researchers suggested that these observations were due to activation of CaMKII and CREB. On the other hand, cortisol inhibits hippocampal BDNF production and resting BDNF level has inverse relationship to the cortisol concentration (de Assis & Gasanov, 2019), thus exercise- induced changes on BDNF levels are related to blood cortisol levels.

Conclusions

In conclusion, according to the present study results, it can be suggested that supervised physical exercise (SPARK program) improves oxidative stress in boys with autism to some extent by increasing BDNF.

We had some limitations in this study. We did not measure antioxidant markers such as SOD and GPX and cortisol. If we could measure these items, we could explain the effects of physical exercise on MDA in children with autism with more precision. Therefore, future studies are highly recommended to measure more clinical factors if they intend to investigate the effects of physical exercise on MDA in children with autism. Moreover, Regulation of BDNF appears to be dependent on the calcium/calmodulin-dependent protein kinase II (CaMKII) signaling

pathway and the cAMP response element-binding protein (CREB). Thus, it would be worth checking the expression of molecules involved in the above signaling pathway before and after physical exercise.

Acknowledgments The authors gratefully acknowledge the subjects and collaborators who cooperated in this investigation.

Data availability The data associated with the paper are not publicly accessible, and they can be available from the corresponding author on reasonable request (e-mail: mehrzad.moghadasi@gmail.com).

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CHANGES IN THE MORPHOLOGICAL DEVELOPMENT OF YOUTH AGED 16–18 FROM EASTERN POLAND IN THE YEARS 2006–2016–2021

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Abstract On the one hand, the number of individuals with excess body weight is increasing, while on the other, the issue of malnutrition among adolescents is becoming increasingly noticeable. Aim: To determine differences in the magnitude of secular trends in height and body mass, BMI, and the occurrence of underweight, normal weight-to-height proportions, overweight, and obesity in adolescents. Materials and Methods: The study was conducted from 2006 to 2021. Height and body mass were measured, and BMI was calculated. The results were statistically analyzed. Results: In the examined girls and boys in the decade from 2006 to 2016, a slowdown in height growth and slight positive changes in body mass and BMI were observed. The results from 2016 to 2021 confirmed a continued trend of increasing somatic characteristics, mainly body mass. Considering the BMI value in both observation periods, a slight decrease in the frequency of underweight and normal BMI was noted in all groups, while a significant increase in the prevalence of overweight and obesity was observed. Conclusions: The temporal trends presented in this study emphasize the need for regular monitoring of the development of adolescents in eastern Poland, as well as the implementation of proactive public health strategies.

Key words: physical development, BMI, adolescents, secular trend

Introduction

Observations conducted indicate that the average Body Mass Index (BMI) and the prevalence of obesity have increased worldwide (NCD Risk Factor Collaboration, 2017). Despite the fact that the trend of rising overweight and obesity in children and adolescents has slowed down in developed countries (Wabitsch et al., 2014), it continues in developing countries (Rivera et al., 2014). As a result, we can observe a dual threat to the health of children and adolescents. On the one hand, the number of individuals with excess body weight is increasing, and on the other hand, the problem of malnutrition among young people is becoming increasingly visible. According to the analyses

conducted by Garrido-Miguel et al. (2021), the prevalence of underweight in Europe is substantial, totaling around 8-9%, with a sustained upward trend. The coexistence of malnutrition and overnutrition poses a serious problem in most countries, and it is also noticeable in the eastern regions of Poland. Saczuk's research (2018), conducted from 1986 to 2016, indicates that the highest prevalence of both underweight and excess body weight is observed in the youngest age groups, with a lower prevalence among older adolescents.

Over the past fifteen years in Poland, a period of rapid social changes and transformations related to the accession to the European Union has transpired. During this time, an exacerbation of disparities in the economic status of Polish society has been observed, along with evident differences in the nutritional status of children and adolescents, as well as other health indicators. This issue is noticeable in regions with higher economic indicators (Gomula et al., 2021) and is beginning to be recognized in areas with a slower pace of development (Wasiluk & Saczuk, 2015). Conversely, the last five years have seen, on the one hand, a change in lifestyle associated with the COVID-19 pandemic. Since 2019, there has been a restriction of physical activity for children, adolescents, and adults due to quarantine measures (Dz. U. 2021 r. poz. 2069, 2120, Dz. U. 2022 r. poz. 64, 655, 974). On the other hand, this period follows the implementation of the "Family 500+" program in the realm of social policy, aimed at supporting families in raising children through monthly childcare benefits of PLN 500 per child in the family (Dz. U. 2016 poz. 195). Therefore, the objective of this study is to determine the differences in the magnitude of secular trends in height and body mass, BMI, and the prevalence of underweight, normal weight, overweight, and obesity among adolescents residing in the eastern provinces of the country in the years 2006–2016 and 2016–2021.

Material and Methods

The present study utilized the results of 5306 girls and 5324 boys aged 16–18 residing in the aforementioned eastern voivodeships of the country. The exact number of examined girls and boys, considering their calendar age and observation period, is presented in Table 1.

Table 1. Number of examined students with consideration to observation period, gender, and age

girls				age group	boys			
2006	2016	2021	Total	(years)	2006	2016	2021	Total
1053	398	380	1831	16	927	504	338	1769
948	344	430	1722	17	882	475	316	1673
1273	456	535	2264	18	1252	385	637	2274
3274	1198	1345	5817	Total	3061	1364	1291	5716

The research was conducted among children and adolescents aged 7 to 19 in the Podlaskie, Lublin and Podkarpackie voivodeships in 2021 and 2022. This study served as a continuation of observations carried out in 2005 and 2006, as well as 2015 and 2016, within the statutory research framework of the Academy of Physical Education in Warsaw (D.S. 49 and D.S. 203). For the first time in the series of studies, 90 schools were randomly selected from the list of educational institutions obtained from the Education Boards, striving to maintain equal representation in all voivodeships. All students in each school were included in the measurements. In accordance with the settlement structure of the voivodeships, efforts were made to maintain comparable populations of residents in rural and urban areas.

With the consent of the main project coordinator, the results of measurements conducted in 2021 as part of the "Active Return to School - PE with the AWF" program in the Podlaskie, Lubelskie, and Podkarpackie voivodeships were also included in this study. The results gathered from the aforementioned projects were combined for further analysis.

Measurements at three observation points were conducted while maintaining the same research methodology. The research was conducted in accordance with the principles outlined in the Declaration of Helsinki and was approved by the Senate Ethics Committee at the University of Physical Education in Warsaw. Data collected through the survey included information about the date of birth and environmental conditions in which the participants were raised.

Anthropometric measurements were carried out following the adopted anthropometric techniques (IBP, 1969), including measurements of height and body mass, from which the body mass index (BMI) was calculated, indicating body mass in kilograms per square of height in meters.

In age groups, considering gender, arithmetic means and measures of dispersion for height, body mass, and BMI were calculated. These statistics were computed using data from 2006, 2016, and 2021. Subsequently, differences in the mentioned somatic indicators were calculated between the study periods. After obtaining these statistics, arithmetic means and measures of dispersion were calculated for the analyzed features, providing an overall picture of trends in the developmental indicators.

Statistical significance of differences between the groups was verified using analysis of variance (ANOVA) and the Newman-Keuls test, at the significance level ($p \leq 0.05$). From the research material, individuals with underweight and overweight, as well as those with normal weight-height proportions, were selected.

The classification into the above-mentioned groups was based on cutoff values developed by Cole et al. (2000, 2007). The obtained sample sizes allowed for the calculation of the percentages of girls and boys in I° (low underweight), II° and III° underweight, normal BMI, overweight, and obesity. Due to the small sample sizes of individuals with II° and III° underweight, these groups were combined into one category (severe underweight).

These calculations were performed at subsequent observation points. From the obtained percentages of each BMI group, differences between the years 2016 and 2006, as well as 2021 and 2016, were calculated, allowing for the determination of the magnitude and direction of changes. Statistical significance of differences in the number of individuals classified into each of the described BMI groups was determined using the χ^2 test, at the significance level ($p \leq 0.05$).

Results

From 2006 to 2016, the height of girls from the cities of eastern Poland increased on average by 0.16 cm (Figure 1, Table 2). The most significant statistically significant changes were observed in seventeen-year-olds (1.41 cm), while in other age groups, the differences between the described study periods were minor. Over the mentioned decade, larger differences in the values of this somatic characteristic were observed in boys, with an average difference calculated from all age groups being 1.28 cm. The most significant changes in height values were observed in eighteen-year-olds (1.83 cm) and sixteen-year-olds (1.79 cm), while the smallest changes were noted in seventeen-year-olds (0.1 cm).

In the years 2016–2021, the height of young females from eastern Poland increased by an average of 0.27 cm. The most significant, statistically significant differences were observed in sixteen-year-olds (1.89 cm). In the other

age groups, there were no significant differences, and they amounted to 1.10 cm at the age of 17 and 0.01 cm at the age of 18. For boys during the analyzed period, greater variations in this somatic trait were noted. The average difference in height between 2021 and 2016 was 1.29 cm. The most significant, statistically significant changes were observed in seventeen-year-olds (2.61 cm) and sixteen-year-olds (1.78 cm). In 2016 and 2021, the results obtained for eighteen-year-olds were at a similar level, with a difference of –0.53 cm.

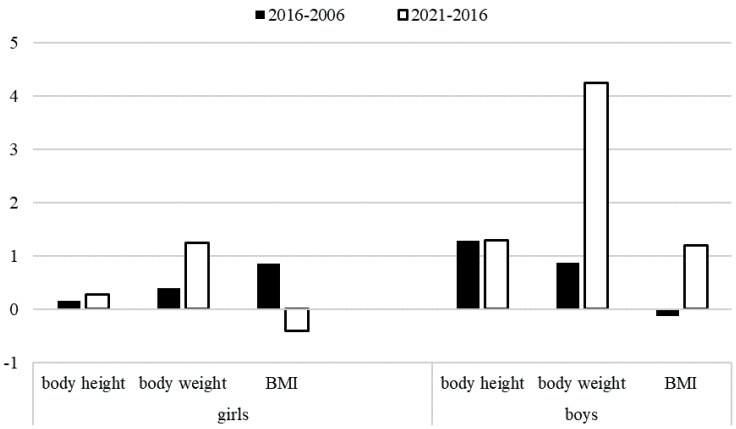


Figure 1. Differences in somatic indices of girls and boys

In body mass among girls between 2006 and 2016, substantial statistically significant changes were also observed in all age groups. Specifically, an increase in this somatic characteristic was noted among seventeen-year-olds by 1.58 kg and sixteen-year-olds by 0.90 kg. A regression in body mass of 1.21 kg was identified in eighteen-year-old girls. Thus, the average value of changes calculated across all age groups was 0.39 kg.

In boys, the mentioned somatic characteristic increased on average by 1.24 kg. Significant increases in body weight were observed only in eighteen-year-olds, with an average increment of 2.76 kg. In younger age groups, differences were small and statistically insignificant ($p > 0.05$).

Greater values of secular trends in body mass were observed in the years 2016–2021. Among female residents of eastern Poland in 2021, a higher value of this somatic characteristic was noted, on average, by 0.87 kg compared to the results obtained in 2016. A significant acceleration was observed in eighteen-year-old females (2.74 kg). Among younger female students, the averages from both described observation periods were at a similar level. During the same time frame, among males, body mass increased on average by 4.25 kg, with statistically significant differences noted in sixteen-year-olds (8.18 kg) and seventeen-year-olds (4.25 kg).

Table 2. Somatic characteristics and BMI of girls and boys considering the research period

age group (years)	research term						Anova	Newman-Keuls test		
	2006		2016		2021			2006-2016	2006-2021	2016-2021
	$\overline{x}$	SD	$\overline{x}$	SD	$\overline{x}$	SD				
girls – body height										
16	165.40	5.99	164.75	5.94	166.64	5.85	10.40	2.67	4.92*	6.30*
17	166.54	6.19	167.95	5.91	166.85	6.32	6.66	5.14*	1.22	3.49*
18	166.89	6.10	166.61	5.86	166.62	7.06	0.65	1.15	1.18	0.04
girls - body weight										
16	55.24	6.68	56.14	7.60	56.87	8.34	7.28	2.98*	5.32*	1.99
17	56.51	7.24	57.99	6.92	58.21	9.01	9.40	4.34*	5.40*	0.56
18	57.16	6.97	55.95	9.43	58.71	9.63	14.30	3.83*	5.19*	7.47*
girls - BMI										
16	20.19	1.76	20.94	2.56	20.45	2.58	17.81	8.42*	2.87*	4.51*
17	20.37	1.74	21.53	1.92	20.88	2.84	39.93	12.40*	5.90*	6.05*
18	20.52	1.98	21.16	3.25	21.10	3.01	15.96	6.52*	6.26*	0.52
boys – body height										
16	173.64	8.17	175.43	8.30	177.21	7.22	26.42	5.69*	9.89*	4.46*
17	175.99	8.53	176.20	7.31	178.81	6.80	15.60	0.66	7.71*	6.44*
18	177.49	6.97	179.32	5.95	178.79	8.69	12.42	6.05*	5.15*	1.58
boys – body weight										
16	65.73	10.08	65.17	11.09	73.35	11.77	73.26	1.34	15.83*	15.36*
17	68.82	9.83	69.26	10.57	73.27	11.10	22.61	1.06	9.33*	7.59*
18	71.03	8.76	73.77	9.10	74.33	13.12	26.09	6.51*	9.39*	1.20
boys - BMI										
16	21.80	2.16	21.09	2.65	23.33	3.22	80.22	7.16*	13.43*	17.78*
17	22.30	1.90	22.24	2.63	23.33	3.22	25.50	0.61	9.39*	8.93*
18	22.55	1.73	22.92	2.40	23.15	3.36	13.90	3.73*	7.25*	2.10

* statistically significant difference at the level of $p \leq 0.05$

The Body Mass Index (BMI) of girls aged 16–18 years increased by an average of 0.85 kg/m² from 2006 to 2016. A statistically significant increase in BMI values was observed in participants at the age of 17 by 1.16 kg/m², at 16 by 0.75 kg/m², and at 18 by 0.64 kg/m². During the same period of research, boys in all age groups experienced a decrease in BMI levels by an average of –0.40 kg/m². The most substantial, statistically significant deceleration was observed in seventeen-year-olds (–0.65 kg/m²), followed by sixteen-year-olds (-0.49 kg/m²). Among the oldest age group, in 2006 and 2016, the results were at a similar level.

In the last five years, significantly smaller changes in the BMI of girls and larger changes in boys were observed compared to the entire preceding decade. Among girls, from 2016 to 2021, the Body Mass Index decreased on average by –0.13 kg/m², while among their male counterparts, it increased by 1.19 kg/m². Noteworthy reductions in the Body Mass Index were observed first among sixteen-year-old girls (–0.71 kg/m²), and increases were noted among eighteen-year-olds by 0.37 kg/m², whereas the smallest changes were observed among seventeen-year-olds (–0.06 kg/m²). Conversely, among the surveyed boys, the most significant changes were observed at the age of 16 (2.24 kg/m²) and 17 (1.09 kg/m²). The smallest changes were observed among eighteen-year-olds (0.23 kg/m²).

The depiction of secular trends in the body mass index (BMI) presented above is somewhat flattened and illustrates the results for all examined individuals. However, it is intriguing to explore the changes in the frequency of normal weight-for-height proportions and the various degrees of underweight, overweight, and obesity among girls and boys. From the data presented in Figure 2 and Table 3, it can be observed that among girls from eastern Poland between 2006 and 2016, there was a statistically significant increase in the percentage of girls with severe underweight (III° and II° underweight) by 1.29%, as well as overweight (2.33%) and obesity (2.94%). Conversely, between 2016 and 2021, a significant reduction in the frequency of severe underweight (III° and II°) by 2.40% and obesity by 2.39% was noted among the assessed female students. Additionally, in this five-year period, an increase in the frequency of overweight by 2.52% was also observed. In other groups, the differences were small and not statistically significant.

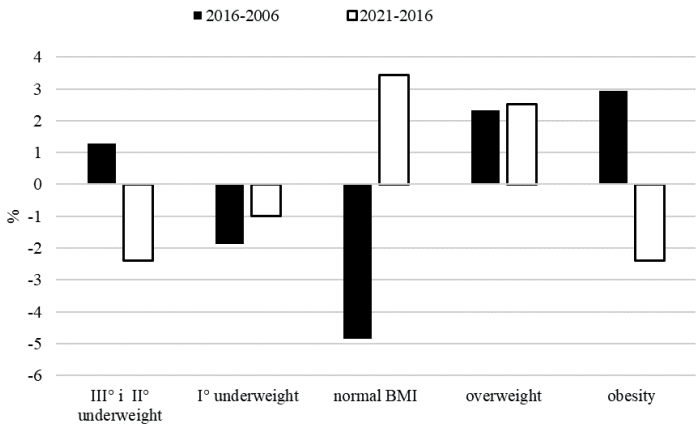


Figure 2. Differences in the percentage change in BMI categories among girls in the years 2016–2006 and 2021–2016

Based on the data presented in Figure 3 and Table 3, a significant increase in the prevalence of overweight (2.31%) and obesity (2.89%) was observed among boys residing in eastern Poland between the years 2006 and 2016. Subsequently, from 2016 to 2021, a statistically significant increase in the prevalence of overweight by 6.23% and normal height-weight proportions by 7.97% was noted. No statistically significant differences were observed in the unmentioned groups. It is noteworthy that the described changes influenced the percentage of normal height-weight proportions among the examined population in eastern Poland. In the first assessed decade, there was a decrease of –4.84% in girls, whereas in the following five years, it increased by 3.43%. Meanwhile, in boys, it decreased by –5.90% and –5.84%, respectively.

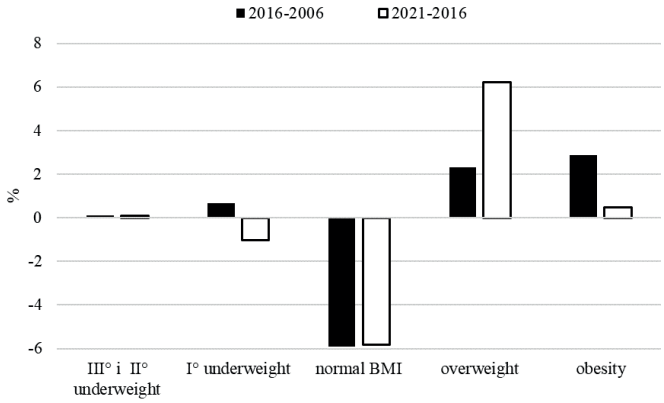


Figure 3. Differences in the percentage change in BMI categories among boys in the years 2016–2006 and 2021–2016

Table 3. Percentage of examined girls and boys in the years 2006, 2016, and 2021 in groups with underweight and overweight, normal BMI, and χ^2 test values for differences between observation periods

	research term			χ^2 test values		
	2006	2016	2021	2006–2016	2006–2021	2016–2021
			% girls			
III° and II° underweight	4.83	6.12	3.72	2.951	2.888	7.320*
I° underweight	13.96	12.08	11.08	2.365	6.129*	0.500
normal BMI	77.54	72.71	76.13	1.759	0.155	0.585
overweight	3.55	5.88	8.40	11.714*	44.715*	5.394*
obesity	0.12	3.06	0.67	90.305*	10.726*	21.271*
			% boys			
III° and II° underweight	0.90	1.00	1.08	0.111	0.366	0.0496
I° underweight	2.59	3.27	2.25	1.774	0.504	2.5136
normal BMI	81.92	76.01	70.18	2.746	10.594*	1.8104
overweight	13.85	16.16	22.39	3.539*	38.449*	11.4477*
obesity	0.74	3.63	4.11	54.484*	64.219*	0.3792

Discussion

The phenomenon of societal tallness, the increase in body mass relative to height, and changes in the rate and magnitude of secular trends in these traits are dependent, among other factors, on the socio-economic environment and living conditions of the population. Smaller changes were observed in girls and boys from countries with lower living standards. However, as these standards improve, these differences increase, as confirmed by research results from countries with rapid economic growth. Additionally, in highly industrialized countries, a weakening of the magnitude of height trends in the population is observed, with an accelerated increase in body mass (Fudvoye & Parent, 2017). It is essential to emphasize that significant differences in the height of youth from economically developed countries in Europe or the USA continue to be observed (Danubio & Sanna, 2008). Conversely, body mass is less genetically determined and more influenced by the environment in which boys and girls reside.

The socio-economic changes that occurred after Poland's accession to the European Union had a significant impact on the magnitude of the secular trend in somatic development. Among girls and boys in selected regions of the country observed from 1966 to 2012, a positive secular trend was noted in both height and BMI, except for the relative body mass of girls aged 14–18 (Kozieł et al., 2014). The authors observed greater changes in height between 1966–1988 compared to 1988–2012. In contrast, differences in the body mass index were more pronounced in the period 1988–2012, corresponding to the post-transitional and post-accession period to the European Union. Dobosz (2012), conducting observations on a large nationwide sample, noted a slowdown in the pace of height increase in children and adolescents from 1999–2009 compared to the 1989–1999 decade, as evidenced by the results for the oldest youth. However, in younger age groups, there was a continued acceleration of developmental processes, manifested as growth and maturation acceleration. The observed high pace of dynamic changes in body mass, especially among the youngest, was also maintained. The consequence of changes in height and body mass is a significant increase in the BMI index, especially in younger children. Similar observations were described by Saczuk (2018).

It is crucial to note that during the same period, the secular trend in somatic characteristics varied depending on the surveyed area. In children and adolescents from Krakow, between 2000–2010, the average body height slightly increased (by approximately 1.00 cm), accompanied by a greater increase in body mass and BMI (Kowal et al., 2011). Greater growth distances were observed among female students in primary and secondary schools in Lower Silesia, between 2001–2002 and 2010–2011. The average height of girls increased from 1.75 cm to 2.45 cm. Substantial increases in average body mass and BMI were also noted (Ignasiak et al., 2016). Similarly, in girls and boys from eastern regions of Poland, between 1986–2006, an increase in body height and a significant increase in body mass were observed, translating into higher values of the body mass index. It is essential to emphasize that the most significant changes were observed in the 1996-2006 decade, particularly in prepubertal and pubertal periods in girls, indicating an acceleration of maturation (Saczuk, 2018). Bartkowiak et al. (2021) also presented significant secular changes in the height and body mass of rural female students in central-western Poland from 1986-2016. Over the analyzed three decades, the authors recorded an average increase in girls' body height by 4.65 cm and body mass by 5.20 kg.

In the examined girls, between 2006 and 2016, similar to the observations of the authors cited above, a deceleration in tallness was observed, accompanied by slight positive changes in body mass and BMI. However, in the subsequent five years, there was a tendency to increase the magnitude of the discussed somatic characteristics compared to the previous decade. Nevertheless, the body mass index showed a decrease. A similar direction of changes, with higher values, was noted in boys from eastern Poland. Between 2016 and 2021, despite the shorter observation period, a significantly greater increase in the described developmental indicators was observed, especially in body mass. Alarming are the changes described in the BMI values. It can be expected that the younger generation will be characterized by excess body mass in further stages of ontogenesis. These assumptions are confirmed by the results of the frequency of underweight and overweight. In both the analyzed decade and the last five years in the studied youth, there was a slight decrease in the frequency of underweight and normal height-weight proportions in all groups, while a significant increase in the frequency of overweight and obesity was noted. It should be noted that there is currently a global trend of decreasing the number of children and adolescents with underweight and increasing the number with excess weight. This is confirmed by studies such as Ng et al. (2014) conducted from 1980–2013 in many countries worldwide. Such a trend can be observed in both developing and

economically highly developed countries. Similar conclusions, based on research on girls and boys from Brazil, China, Russia, and the USA, were presented by Wang et al. (2002), and from Australia by Hardy et al. (2017). These authors attribute the reasons for these changes to different dietary habits and a reduction in physical activity. Hardy et al. (2017) emphasize that the trend of increasing excess body weight in developed countries is slowing down.

The lack of an increase in the frequency of underweight can be considered optimistic. Underweight is a significant issue among children and adolescents, both clinically and in terms of public health. It is associated with adverse health effects at all stages of human life and may reflect poverty in access to food (Ieiri et al., 2021), unhealthy eating habits (Rawal et al., 2021), or an increased risk of developing various conditions. Children and adolescents with underweight are more susceptible to infectious diseases (Goutines et al., 2021), more likely to have impaired cognitive functions (Suryawan et al., 2022), mental disorders (Donkor et al., 2021; Zeiler et al., 2021), and a lower self-rated health status (Linardon et al., 2021).

The increase in excess body weight and the decrease in underweight among the youth assessed by us were likely influenced by the COVID-19 pandemic and the living environment. The lifestyle of young inhabitants of eastern Poland significantly differs from that of their peers in other regions, as extensively described by Saczuk (2018). Furthermore, starting from 2020, there was a reduction in physical activity among children and adolescents due to the COVID-19 pandemic. During this time, remote learning was conducted for many months, simultaneously closing sports facilities. Additionally, students, mainly staying at home, were deprived of regular, daily interactions with peers, shared play, and physical activity. Hence, the data on screen time for purposes unrelated to education are very alarming. According to the parents of the surveyed children, the number of hours spent in front of the TV, smartphone, or computer increased both during the week (43.6%) and on weekends (37.4%). Similar conclusions were presented by international research studies (Paterson et al., 2021; Stockwell et al., 2021; Manyanga et al., 2023). The introduction of the government's 500+ program in 2016, which provided a monthly allowance of PLN 500 per child, especially supported less affluent families. It is essential to emphasize that according to Eurostat's report (2018), the eastern regions of Poland are among the poorest macro-regions in the European Union, where the income per capita does not exceed 50% of the EU average income. Therefore, the temporal trends presented in this study indicate the necessity of regularly monitoring the development of young inhabitants of eastern Poland, as well as implementing proactive public health strategies.

Conclusions

1. During the analyzed period, individuals from eastern Poland exhibited stabilization in body height, accompanied by an increase in body mass and BMI.
2. Greater variations were observed in the years 2016–2021, coinciding with the duration of the COVID-19 pandemic.
3. The aforementioned observations were further corroborated by the frequency of underweight and overweight occurrences, particularly among boys.

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PHYSICAL EDUCATION TEACHERS AS ADULTS TRAINERS AND THEIR PERCEPTIONS OF THEIR EVALUATION ON VOCATIONAL EDUCATION AND TRAINING

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[A] Study Design; [B] Data Collection; [C] Statistical Analysis; [D] Manuscript Preparation

Abstract Introduction: Educational systems and related evaluation policies tend to change and adapt to the demands of society all over the world. In Greece, the latest education policy includes the update and adaption of the educational curricula and the introduction of evaluation of teachers and adult trainers on vocational education and training (VET). The evaluation of teachers and trainers involved in the Public vocational training Institutes (VTI) and specifically in the Specialties of Sports' Coach through an effective evaluation process could identify the strengths and weaknesses of the trainers and create professional development opportunities within their knowledge of content, pedagogy, and curriculum. Purpose: The purpose of this study was to investigate the perceptions of Physical Education Teachers who teach as Adult Trainers in public and private VTIs in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor), regarding their evaluation on VET. Methods: In this study, 102 participants (M = 44.9 ±11.02 years old), 55 males (53.9%) and 47 females (46.1%) participated. A relevant questionnaire about Teachers' Evaluation was adapted and

used. Non-parametric statistical tests were applied and descriptive statistics were calculated for all variables. Results: The results showed different perceptions among some items of the questionnaire depending on the work institution - public / private VTIs ($p \leq 0.05$), educational level ($p \leq 0.05$) and teaching experience ($p \leq 0.05$). Conclusions: These results underscore the complexity and variability in perceptions of educational evaluation. These findings suggest the importance of considering various factors, such as institutional type, teaching experience, and educational level, in the design and implementation of evaluation systems to ensure they are effective, equitable, and conducive to professional growth.

Key words: sports coach, PE teachers, education, assessment, vocational education, adult education

Introduction

As stated by Matsagouras (2007) definition of evaluation, educational evaluation refers to a systematic, valid, reliable, objective, and organized array of individual procedures, with procedures that are specifically designed to assess and measure the effectiveness of teaching methodologies, the performance of teachers, the progress of students, the efficacy of the curriculum, and the overall functioning of the school system and plays a crucial role in enhancing the feedback of the educational process (Matsagouras, 2007). Educational systems and related evaluation policies tend to change and adapt to the demands of society all over the world, i.e., the update of educational curricula and the introduction of a Teachers' and Adult Trainers' evaluation system in the case of Greece (Law 4763/2020; Law 5029/2023).

Regarding evaluation systems in education, there are different systems and different views and perspectives among teachers and trainers about their evaluation. For example, the Finnish model of evaluation (Tarhan et al., 2019) utilises flexible methods of evaluation and aims to understand educational needs, while promoting the professional development of teachers (Organisation for Economic Co-operation and Development, 2009; 2016; Tarhan et al., 2019). Teacher evaluation in Finland is a more team-based, reflective and participatory process, with the aim of creating professional learning communities among teachers and administrators (Sahlberg, 2021; Webb et al., 2004). The municipality and school principals carry out teacher evaluation, while the government is not involved in any part of the evaluation process (Finnish National Board of Education, 2012; Tarhan et al., 2019). The principals are also responsible for hiring the teacher and for arranging the school budget provided by the municipality (Sahlberg, 2010; 2021), while the government expects each municipality to fund schools with enough resources so that the teachers can have the opportunity for professional development activities (Williams & Engel, 2012). In Italy, there is not a specific legislative framework exclusively for teachers' evaluation (Tarhan et al., 2019). Regarding teachers' and trainers' views on evaluation, in Finland teachers accept evaluation, while in Italy and Greece they have a predominantly negative view, while several neutral views are also reported (De Angelis et al., 2015; Papakonstantinou & Kolympari, 2019; Tarhan et al., 2019). Evaluation is advised to focus on the quality of teaching and pedagogical practices (Collins, 2004; Ingersoll & Collins, 2019; Robinson & Campbell, 2010), while the impact on teaching staff can be direct or indirect, such as promotion and improvement of teachers' professional profile, respectively (Altrichter & Kemethofer, 2018; Mathison, 2010).

Specifically, the evaluation framework in Greece for the public VET trainers (Law 4763/2020; Law 5029/2023) is carried out through a four-point descriptive scale (excellent, very good, satisfactory and inappropriate). Law 4763/2020, as amended by Law 5029/2023 contains provisions for the implementation of an evaluation system

of the work of the Directors, Deputy Directors and Vocational Training Instructors of the Public Vocational Training Institutes. Trainers are evaluated on four main pillars:

A) The educational work, the pedagogical climate and the management of the department.
B) Consistency and competence of the trainer.
C) In the self-evaluation report of the project, prepared by the vocational training Trainers themselves, one month before the end of the training semester, which is submitted to the Director and the Deputy Director of the VTI.
D) The evaluation of the work of the trainers by the trainees of VTI, through an electronic evaluation platform. The evaluation is anonymous and refers for example, to the evaluation of the course, the evaluation of the trainer, the learning outcomes and the relations between the trainer and the trainees.

Regarding Pillar A for the educational work provided, pedagogical climate and management of the department, the evaluation process is carried out by the Director and the Deputy Director of the VTI. The evaluation criteria for this pillar are:

i. Preparation of the course, provision and electronic posting of the necessary educational material in accordance with the provisions of the Training Guidelines.
ii. Readiness in terms of the subject matter of the training, degree of updating of knowledge and successful transformation of the subject matter to meet the needs of the adults' training, with an assessment of its scientific and practical validity.
iii. Commitment to achieving the expected learning outcomes.
iv. Methodology and use of digital media in teaching.
v. Pedagogical climate, contribution to the active participation of trainees in the training process, management of the department - conflict resolution, promotion of a spirit of mutual trust, mutual respect and equal treatment of all trainees without discrimination and exclusion.

Regarding Pillar B for the consistency and competence of the trainer, the evaluation process is also carried out by the documented by the Director and the Deputy Director of the VTI. The evaluation criteria of this pillar are:

i. Consistency and interest in the performance of the obligations and duties of the trainer as well as his/her response to the institutionalized framework of the VTI.
ii. Timely and correct updating of the service records (absence register, books of taught material).

Regarding the Pillar D of the evaluation of the work of public VTIs by the trainees and the anonymous evaluation platform, the results of this evaluation is communicated by the Documentation and Communication Directorateto Planning and Development Directorate of the General Secretariat of Vocational Education, Training, Lifelong Learning and Youth of the Ministry of Education and Religious Affairs to the Director and Deputy Director of the VTI, (Law 4763/2020; Law 5029/2023).

The research community is engaged in various issues related to education and the training of coaches of different Specialties in sport (Athanailidis et al., 2015; 2016; Bazylchuk et al., 2018; Deligiannidou et al., 2019; Bezkopylnyi et al. 2019; Matthew, 2015; Laios, 2005; Richards et al., 2018), as well as the implementation of evaluative systems in PE teachers and related fields of sports (Gargalianos & Matsaridis, 2017; Kipreos et al., 2016; Todd, et al., 2016). Regarding Greek sports and education, researchers report that although the field of sport in Greece is growing, a lack of strategic planning and qualified sport managers is highlighted and may act as a hindrance (Gargalianos & Matsaridis, 2017). Further specialisation and training could have a positive impact on

the level of knowledge and skills of coaches (Protsenko et al., 2016; Soltyk et al., 2017). In the research of Kipreos et al., (2016) where the evaluation factors of coaches were examined according to demographic characteristics (gender, level of education, teaching experience, coaching experience), no significant differences were found, except on the variable level of education, where coaches who held a doctorate recorded statistically significantly lower evaluation values in terms of the importance of coaches' evaluation criteria. However, other studies refer to the importance of education, updating knowledge and professional development, while coaches who had higher averages in their coaching performance and levels of cooperation with other colleagues had participated in several training sessions (Athanailidis et al., 2016). Furthermore, evaluation is often linked to the need for training of trainers (Valcke et al, 2007), while further education and professional training is important for the development of trainers (Edy, 2020; Villegas-Reimers, 2003).

The evaluation of teachers and trainers in the various sport coach specialties is limited depending on the country and the sport in which it is investigated (Freitas, et al., 2013; Lyle, 2005; 2016; Stefanik, 2013). The evaluation of the trainers involved in the VTIs in the Specialties of Sports Coaches could identify the strengths and weaknesses of the trainers, in order to record them, and also promote sports trainers to improve through relevant trainings and courses in Adult Education. Therefore, the purpose of this research is to investigate the perceptions of Physical Education Teachers who work as Adult Trainers operating in public and private VTIs in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor), regarding their evaluation on the Vocational Training Institutes.

Material & methods

Participants

The participants in this study were 102 (Mage = 44.9 ±11.02 years) Physical Education Teachers-Adult Trainers operating in public and private VTIs in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor).

Of the participants, 55 were male (53.9%) and 47 were female (46.1%). The sample of the present study consisted of higher education graduates of Physical Education and Sport Department in the country or abroad (Figure 3), of which the majority (54.9%) were working in public and 45.1% in private VTIs. Regarding the participants' previous experience, the majority of them had 4–10 years of teaching and professional experience (Figure 1 and Figure 2). Regarding the possession of a certificate in new technologies and computer use, the majority of participants (80.4%) held a relevant certificate, while 54.9% knew one foreign language, 37.3% knew two foreign languages and 7.8% knew none.

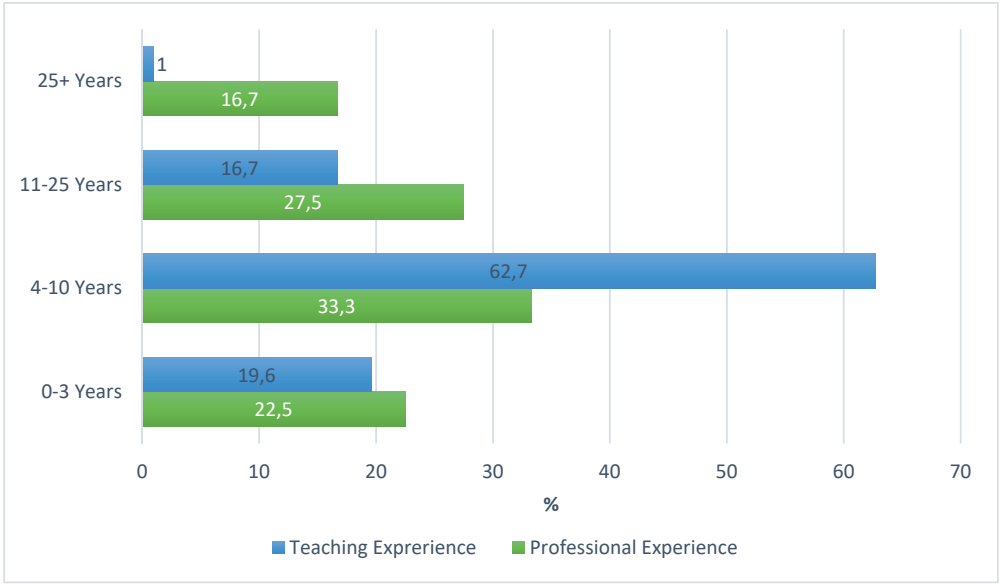


Figure 1. Teaching and professional experience of participants

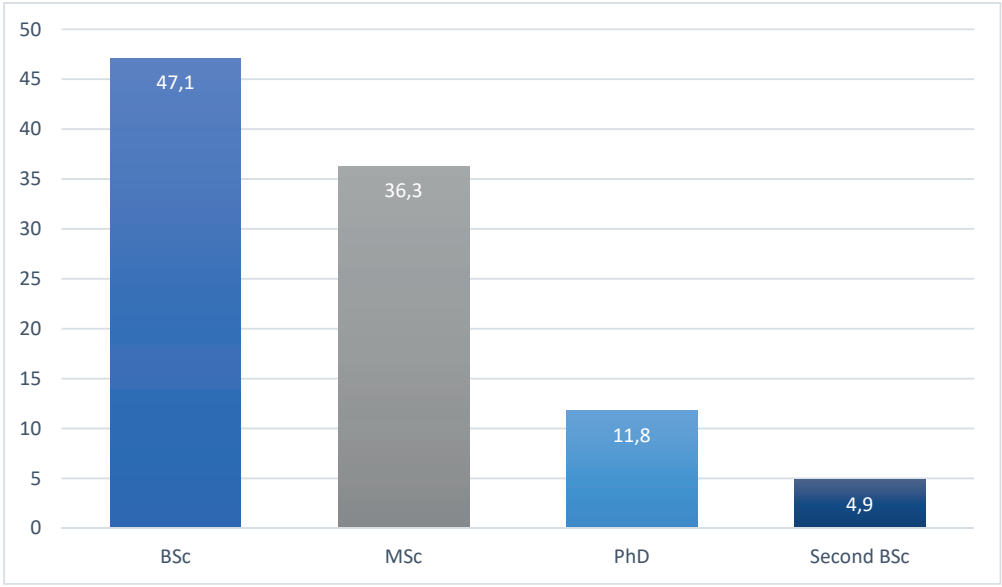


Figure 2. Educational Level of participants

Procedure

The research procedure chosen is the quantitative determination of the perceptions regarding the evaluation of Physical Education Teachers-Adult Trainers operating in public and private VTIs in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor), through a quantitative survey (Bryman, 2003; 2016; Kyriazi, 2011; Tsiolis, 2011). By measuring theoretical concepts through a questionnaire (Bryman, 2016; Cohen & Hill, 1998; Cohen et al., 2007; Papageorgiou, 2014), researchers are given the opportunity to quantify and compare data between variables (Kyriazi, 2011).

In the present study, the ethical principles of Declaration of Helsinki (World Medical Association, 2010) had been followed. Participation was anonymous and voluntary, in accordance with the principles of the research process (Mertens, 2009), while the sampling method was that of non-probability sampling, specifically convenience sampling (Zafeiropoulos, 2005). Specifically, prior to the submission of questionnaires, all participants involved in this study provided written consent. This consent was obtained after the participants were thoroughly informed about the research procedures, the objectives of the study, and the intended use of the data collected. The information provided to the participants included detailed explanations of the research methodology, the scope and purpose of the research, the nature of the questions in the questionnaire, and assurances regarding the confidentiality and anonymity of their responses. The process of obtaining consent was conducted in accordance with ethical guidelines to ensure that all participants were fully aware of their involvement in the study and the implications thereof. Participants were also informed of their right to withdraw from the study at any point without any adverse consequences. The Physical Education Teachers-Adult Trainers were recruited from both public and private VTIs participated in this study, although the evaluation introduced by the state is for public VTIs only. However, evaluation procedures are also implemented in private VTIs, therefore it was deemed appropriate to explore the differences between private and public VET.

Research tool

The investigation of the perceptions of Physical Education Teachers-Adult Trainers operating in public and private VTIs in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor), regarding their evaluation, was conducted through a questionnaire designed for school teachers and educators regarding their perceptions about evaluation that has been designed by Kapachtsi (2007) and has been applied in similar studies (Kapachtsi, 2013) in large populations (482 school teaches), with high reliability (Cronbach's a = 0.85), and has been used in similar surveys (Kapachtsi, 2007; 2008; 2013). This instrument consists of five parts and is composed of a total of 48 statements, which are answered through a five-point Likert scale from 1 = "I strongly disagree" to 5 = "I strongly agree". The first part consists of 6 statements (e.g., "A1. Evaluation leads to the qualitative improvement of education."), the second part includes 8 main statements with sub-questions (e.g., "B7. The teaching and pedagogical competence of the trainer should be judged on the basis of: B7A. the use of new teaching methods."), the third part comprises 8 main statements with sub-questions (e.g., "C15. Suitable for evaluators are: C15B. The teachers' association and the director - deputy director."), the fourth part is made up of 12 statements (e.g., "D23. The evaluation must be based on a descriptive report by the directors and deputy directors."), and the fifth part contains 3 main statements with sub-questions (e.g., "PART E E35. I consider my knowledge of educational evaluation to be satisfactory.").

In addition, six statements were reversed (A3, A6, B9, B12, B14, C20) as the instructor of the instrument suggest. These statements were reversed during statistical processing and in the presentation of the results (Table 2), so that the highest value expressed the most positive attitude. Because the instrument was initially designed for primary and secondary school teachers, some adjustments had to be made in some statements in order to correspond to the Adult Vocational Education and the evaluation structure of the recent law (Law 4763/2020; Law 5029/2023). These adaptations involved adjusting the terms teachers=teachers and trainers, pupils=students, and in the evaluation bodies. The Cronbach's a of the instrument in previous studies (Kapachchi, 2007; 2008) was satisfactory (Cronbach's a = 0.85), as well as in the present study despite the adjustments made (Cronbach's a = 0.74).

Statistical analysis

The software IBM SPSS Statistics for Windows software, Version 25.0, Armonk, NY, IBM Corp, (IBM, 2017) was used for the statistical analysis. In this study, the effect size was assessed using two distinct metrics: the rank-biserial correlation coefficient (r) and eta squared (η^2). The interpretation of the rank-biserial correlation coefficient (r) values followed a specific framework within the context of effect strength, where an r value less than 0.3 indicates a small effect, an r value between 0.3 and 0.5 suggests a medium effect, and an r value greater than 0.5 signifies a large effect. Additionally, eta squared (η^2) was utilized to quantify the effect size, with η^2 values interpreted on a distinct scale: a value of 0.01 indicates a small effect, 0.06 represents a medium effect, and 0.14 or higher reflects a large effect. Statistical tests (Mann-Whitney-U-Tests and Kruskal-Wallis H tests) were applied and descriptive statistics were calculated and recorded for all variables. The level of statistical significance was set at $p \leq 0.05$.

Results

Table 1 shows the means and standard deviations for all items in the questionnaire, as well as the percentage of participants who agree or strongly agree with the statements about the evaluation. Responses to questions A3, A6, B9, B12, B14, C20, of the questionnaire were reversed during statistical processing and in the presentation of the results (Table 2), so that the highest value reflects the most positive attitude.

Table 1. Means, standard deviations and percentages for all the questions of the questionnaire

	M-SD	%*
PART A		
A1. Evaluation leads to the qualitative improvement of education.	3.79 ±1.27	66.7
A2. The state that supports and maintains public education has the right to evaluate.	3.37 ±1.25	52.9
A3.** Evaluation can reduce the teacher's authority.	3.80 ±0.82	62.7
A4. The professional development of the trainer should be based on his/her evaluation.	3.29 ±1.23	46.1
A5. The evaluation of the trainer is an important feedback process.	3.36 ±1.14	55.9
A6.** Evaluation can reduce the trainer's autonomy in carrying out his/her work.	3.60 ±0.78	57.8
PART B		
B7. The teaching and pedagogical competence of the trainer should be judged on the basis of:		
$B7_A$. the use of new teaching methods.	3.63 ±1.03	55.9
$B7_B$. the activation of its students and their participation in the educational process.	3.95 ±0.83	75.5
$B7_C$. its contagiousness.	3.70 ±0.95	57.8
$B7_D$. its ability to address learning difficulties.	3.65 ±0.89	59.8
$B7_E$. the use of multiple methods of student assessment.	3.15 ±1.01	27.5

	M-SD	%*
PART B		
B8. The teacher's initiatives in the formulation of school unit objectives should be evaluated.	3.66 ±0.96	56.9
B9.** Student performance should not be a criterion for teacher evaluation.	3.63 ±0.88	56.9
B10. The cooperation of the trainer with the director should be an evaluation criterion.	3.36 ±0.89	40.2
B11. The teacher's behaviour in the classroom should be evaluated.	3.68 ±0.91	58.8
B12.** The introduction of innovative activities in the school is not a criterion for teacher evaluation.	3.40 ±1.09	52.9
B13. The trainer's individual qualification file should be taken into account in the evaluation process.	3.92 ±0.85	69.6
B14.** The ethics of the trainer is not an area for evaluation.	3.75 ±1.00	65.7
PART C		
C15. Suitable for evaluators are:		
$C15_A$. University Committee.	2.66 ±0.91	17.6
$C15_B$. The teachers' association and the director - deputy director.	2.73 ±1.15	24.6
$C15_C$. The Head of the Directorate of Design and Development Directorate of Vocational Education, Training and Lifelong Learning, the Head of the Documentation and Communication Directorate of Vocational Education, Training and Lifelong Learning	2.77 ±0.85	17.6
$C15_D$. Committee from the Ministry of Education, Research and Religious Affairs–Youth and Lifelong Learning Foundation.	2.78 ±0.81	15.7
$C15_E$. The Head of the Directorate for the Supervision of Vocational Training and Lifelong Learning Institutions of the General Secretariat for Vocational Training and Lifelong Learning.	2.62 ±0.83	9.8
C16. The evaluation of trainers must be carried out by Permanent Assessors.	2.75 ±0.80	15.7
C17. The head of the school unit should evaluate the teacher's initiative.	2.76 ±0.84	16.7
C18. Local authorities should not be involved in the teacher evaluation process.	2.64 ±0.75	11.8
C19. Students should have a say in the evaluation.	2.59 ±0.87	13.7
C20.** I consider the parents of students inappropriate to be involved in the evaluation process.	2.58 ±0.76	7.8
C21. A consultant is the one who should evaluate the teacher's scientific training.	2.68 ±0.86	12.7
C22. Representatives of trainers' trade unions should not be involved in the evaluation process.	2.66 ±0.97	16.7
PART D		
D23. The evaluation must be based on a descriptive report by the directors and deputy directors.	3.55 ±0.98	52.9
D24. The method of observation by the assessors in the classroom is considered essential in the evaluation process.	3.18 ±0.97	49.0
D25. Evaluation based on video recording of lessons is the most appropriate method.	3.51 ±0.75	43.1
D26. The assessment must be based on a descriptive report by the Consultants.	3.65 ±0.76	51.0
D27. Self-evaluation should be taken into account by the evaluators.	4.22 ±0.77	86.3
D28. Student performance tests are necessary in the assessment.	4.04 ±0.74	78.4
D29. Completion of questionnaires by students is the most appropriate method of evaluation.	3.71 ±0.85	64.7
D30. The evaluation should be done once a year.	3.42 ±1.09	58.8
D31 The interview with the trainer cannot be the only way of evaluating the trainer.	4.00 ±0.82	74.5
D32. The points method should be used by evaluators, with regard to the development of the trainer to an educational administrator (head teacher, counsellor, etc.).	4.16 ±0.75	82.4
D33. The low score of the trainer during his/her evaluation should be used for its own feedback and to refer him for training.	3.63 ±0.77	62.7
D34. The evaluation criteria must be known to the trainer from the outset.	3.90 ±0.81	74.5
PART E		
E35. I consider my knowledge of educational evaluation to be satisfactory.	3.08 ±0.93	28.4
E36. My sources of information are:		
$E36_A$. Books and Articles.	2.85 ±0.90	21.6
$E36_B$. Discussions with colleagues.	3.29 ±1.01	54.9
$E36_C$. Discussions with trade unions.	2.86 ±0.96	24.5
$C36_D$. Internet.	3.90 ±0.76	73.5
$E36_E$ Training seminars.	2.97 ±0.78	25.5

* Percentage of participants who agree or strongly agree

** The answers of items A3, A6, B9, B12, B14, C20 were reversed

Regarding gender correlations, where 1 represented males and 2 represented females, distinct correlations were observed with certain items. Specifically, item C15E exhibited a Spearman's r(100) = 0.237 with a p-value of 0.016, denoting a statistically significant positive correlation between gender and the variables addressed by this item. Conversely, item D26 presented a Spearman's r(100) = –0.236 with a p-value of 0.017, indicating a statistically significant negative correlation. No other significant correlations were found for the remaining items. Additionally, for item C15E, the Mann-Whitney U test yielded a statistic of U = 965, p = 0.017, accompanied by an effect size (rank biserial correlation) of 0.253. Similarly, item D26 displayed a Mann-Whitney U statistic of U = 968, p = 0.018, with an effect size (rank biserial correlation) of 0.251. For the rest items no statistically significant differences were observed.

Table 2 shows the items of the questionnaire in which significant differences were found by the non-parametric statistical tests (Kruskal-Wallis) for the perceptions of teachers and trainers depending on the working institution (public/private VTI). Significant differences ($p < 0.05$) were identified, in the statements "A1. Evaluation leads to qualitative improvement of education," "B7A. Instructor's teaching and pedagogical competence should be judged based on the use of new teaching methods" "B7D. The teacher's teaching and pedagogical competence should be judged on the basis of his/her ability to deal with learning difficulties," "B7E. Trainers' teaching and pedagogical competence should be judged on the basis of the use of multiple methods of student assessment, and "B8. The instructor's initiatives in the formulation of school unit goals should be evaluated." In the majority of questions, the Physical Education Teachers-Adult Trainers operating in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor) in private VTIs had statistically higher means than those teaching in public ($p < 0.05$).

Table 2. Items of the questionnaire in which significant differences were found by the non-parametric statistical tests (Mann-Whitney U) for the perceptions of teachers and trainers depending on the working institution (public/private VTI)

Questionnaire Item†	Group	M-SD	U	p	Effect Size (r)
A1	Public VTI	3.59 ±1.29	1013	0.050*	0.214
	Private VTI	4.04 ±1.22			
B7A	Public VTI	3.45 ±1.07	1007	0.050*	0.218
	Private VTI	3.85 ±0.94			
B7D	Public VTI	3.45 ±0.97	959	0.018*	0.256
	Private VTI	3.89 ±0.73			
B7E	Public VTI	2.95 ±0.98	924	0.008*	0.283
	Private VTI	3.39 ±1.02			
B8	Public VTI	3.45 ±0.95	945	0.016*	0.267
	Private VTI	3.91 ±0.91			

*$p \leq 0.05$

†A1. Evaluation leads to the qualitative improvement of education., $B7_{A-E}$. The teaching and pedagogical competence of the trainer should, be judged on the basis of: $B7_A$. the use of new teaching methods., $B7_D$. its ability to address learning difficulties., $B7_E$. the use of multiple methods of student assessment., B8. The teacher's initiatives in the formulation of school unit objectives should be evaluated.

In the following table, questionnaire's data are reported, in which significant differences were identified by the non-parametric statistical tests (Kruskal-Wallis) for the perceptions of Physical Education Teachers-Adult Trainers operating in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor) depending on their teaching experience. In particular, significant differences were found in the statement "B13. The instructor's individual qualification record should be taken into account in the evaluation process" between Instructors who had 0–3 years of teaching experience (M.O. = 4.40 ±0.82) and those who had 4–10 years of teaching experience (M.O. = 3.75 ±0.83 teaching experience ($p \leq 0.05$). Similar differences were found in the statement "D24. The method of observation by classroom evaluators is considered essential in the evaluation process," "D31. Interviewing the instructor cannot be the only way of evaluating the instructor" and in the statement "D32. The points method should be used by evaluators, with reference to the development of the trainer into an educational administrator" (Table 3).

Table 3. Differences based on non-parametric statistical analyses (Kruskal-Wallis) for Trainers' perceptions according to teaching experience

Questionnaire Item†	Group	M-SD	H	p	Effect Size (η^2)
	0–3	4.40 ±0.82			
B13	4–10	3.75 ±0.83	9.04	0.029*	0.089
	11–25+	4.00 ±0.79			
	0–3	3.10 ±0.96			
D24	4–10	3.08 ±1.01	10.09	0.018*	0.099
	11–25+	3.76 ±0.43			
	0–3	4.50 ±0.51			
D31	4–10	3.89 ±0.83	10.79	0.013*	0.106
	11–25+	3.88 ±0.85			
	0–3	4.60 ±0.59			
D32	4–10	4.02 ±0.74	12.34	0.006*	0.122
	11–25+	4.24 ±0.75			

*$p \leq 0.05$

†B13.The trainer's individual qualification file should be taken into account in the evaluation process., D24.The method of observation by the assessors in the classroom is considered essential in the evaluation process., D31The interview with the trainer cannot be the only way of evaluating the trainer., D32. The points method should be used by evaluators, with regard to the development of the trainer to an educational administrator (head teacher, counsellor, etc.).

In Table 4 the questionnaire items are reported, in which significant differences were identified by the non-parametric statistical tests (Kruskal-Wallis) for the perceptions of the Physical Education Teachers-Adult Trainers operating in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor) depending on their educational level. Specifically, item "B7D. The instructor's teaching and pedagogical competence should be judged on the basis of his/her ability to address learning difficulties," significant differences were found between those participants who had a Bachelor's degree compared to those who had a Master's degree, and between those who had a Bachelor's degree and a PhD ($p < 0.05$). In statement "D23. Assessment should be based on a descriptive report by managers and deputy managers", differences were found between those who had a PhD compared to both those who had only a BSc's Degree and those who had a Master's degree.

Table 4. Differences based on non-parametric statistical analyses (Kruskal-Wallis) for the perceptions of Trainers according to educational level

Questionnaire Item†	Group	M-SD	H	p	Effect Size (η^2)
B7D	BSc	3.87 ±0.92	9.35	0.009*	0.092
	MSc	3.46 ±0.83			
	PhD	3.25 ±0.75			
D23	BSc	3.45 ±0.99	7.14	0.028*	0.070
	MSc	3.46 ±0.96			
	PhD	4.25 ±0.75			

*$p \leq 0.05$

†$B7_{A-E}$. The teaching and pedagogical competence of the trainer should, be judged on the basis of: $B7_D$. its ability to address learning difficulties., D23. The evaluation must be based on a descriptive report by the directors and deputy directors.

Discussion

The results from our study reveal significant differences in perceptions of evaluation among trainers, aligning with the perceptions observed in educational evaluation systems globally. These differences are influenced by factors such as the type of vocational training institute, teaching experience, and educational level. In our study, trainers from private vocational training institutes (VTIs) generally exhibited more favorable perceptions towards evaluation methods compared to their counterparts in public VTIs. This finding resonates with the flexible approach to evaluation seen in the Finnish model, as discussed by Tarhan et al. (2019), where the emphasis is on understanding educational needs and promoting professional development, a perspective supported by the Organisation for Economic Co-operation and Development (2009) and Snider (2011). Furthermore, our survey indicated that teaching experience impacts trainers' attitudes towards evaluation. Newer trainers showed different perceptions compared to those with more years of experience. This variation in views among trainers based on experience mirrors the differing national attitudes towards evaluation, such as the general acceptance in Finland and the predominantly negative view in Italy and Greece, as noted by De Angelis et al. (2015) and Papakonstantinou & Kolympari (2019). Additionally, the educational level of trainers also influenced their perceptions of evaluation. This aspect of our findings aligns with the literature's emphasis on the quality of teaching and pedagogical practices in evaluations, as advocated by Collins (2004), Ingersoll & Collins, (2019) and Robinson & Campbell, 2010). The impact of evaluations, as highlighted by Altrichter & Kemethofer (2015) and Mathison (2010), can be multifaceted, affecting aspects such as promotions and professional development.

Specifically, in the present study several significant differences were found regarding the perceptions of Physical Education Teachers-Adult Trainers operating in public and private VTIs in the specialty of Sports Coach (e.g., Soccer Coach, Basketball Coach, Track and Field Coach, Tennis Coach, Strength and Conditioning Coach, AEROBICS Instructor), about their evaluation on VET, depending on the work institution - public / private VTIs, teaching experience and educational level (Bakker et al., 2011; Kafritsa et al., 2021; Kipreos et al., (2016). However, researchers point out the potential influence of the socio-cultural aspects on trainers' views about methods of evaluation on the coaching process (Bakker et al., 2011).

The literature on adult education indicates that teaching adults is approached differently from that of formal education in children and adolescents (Collins et al., 2004; Knowles et al., 2014). School teachers are likely to determine their own teaching methods based on their personal experience and the influence of other teachers (Todd et al., 2016). In contrast, adult education has its own specific characteristics (Thompson, 2018; Tight, 2012)

and in order to transfer the required knowledge, specific adult training methods are needed (Collins et al., 2004; Knowles et al., 2014; Kokkos, 2008). For this purpose, educational level, specialization on Adult Education and teaching experience are crucial factors for a successful and active learning educational environment among adults.

Specifically, it is noted that PE teachers usually choose direct teacher-centered teaching methods because they are more familiar to them and because it is the way they were taught (Gurvitch, et al., 2008; Jose & Lopez, 2023; Kozubal et al., 2022). Regarding teaching experience, it did not affect the teaching of physical education and PE teachers (Hammond, & Perry, 2005; Kipreos et al., 2016). Although in order to create an active and successful educational environment in adult education, researchers suggest additional training of the trainers, about new knowledge and trends among Adult Education, in order to enable them to perform more effectively (Brinia, et al., 2019), especially for those educators who have no teaching experience and exhibit increased educational needs (Kafritsa, et al., 2021).

The evaluation of coaches and the coaching process is limited depending on the country and the sport in which it is investigated, and conclusions cannot be easily generalized (Freitas, et al., 2013; Lyle, 2005; 2016). Although different perceptions of evaluation were identified among Physical Education Teachers-Adult Trainers on their evaluation on VET, an effective evaluation process could have a positive impact on the educational process of adults and on trainers' professional development regarding their knowledge of content, pedagogy, and curriculum. The aim towards further education and training through specific courses in Adults Education could positively contribute to the improvement of their teaching and professional development (Protsenko et al., 2016; Soltyk et al., 2017).

In conclusion, our study's results underscore the complexity and variability in perceptions of educational evaluation, reflecting the diverse approaches and attitudes observed in different educational contexts globally. These findings suggest the importance of considering various factors, such as institutional type, teaching experience, and educational level, in the design and implementation of evaluation systems to ensure they are effective, equitable, and conducive to professional growth. Due to the small size of the study group, the research is of a pilot nature and future researches could be investigate the perceptions of Physical Education Teachers as Adults Trainers regarding their evaluation on vocational education and training more systematically.

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PREVALENCE OF ORTHOREXIA NERVOSA IN A SAMPLE OF ROCK AND SPORT CLIMBERS

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Abstract Orthorexia nervosa (ON) is a disorder characterized by obsessive behavior towards healthy eating. Some groups present a higher prevalence of ON and athletes seem to be a population at risk. The aim of this study was to determine the prevalence of ON in the rock and sport climbing community. Düsseldorf Orthorexia Scale (PL-DOS) was used to assess ON. The study involved 236 climbers (including 159 men and 77 women, 67.4 and 32.6%, respectively), with an average age of 34.7 ±9.2 years. The group was divided into groups according to criteria such as the preferred type and style of climbing, participation in climbing competitions or the volume of training undertaken. Orthorexia was diagnosed in 12.7% (n = 30) of climbers, with a mean score of PL-DOS of 32.8 ±2.4 with a 95% confidence interval ranging from 31.9 to 33.7. Another 25% of the respondents were diagnosed with ON risk (mean ±SD 26.8 ±1.5, 95% CI 36.4–27.2). It was not found that the adopted stratification variables significantly differentiated the groups distinguished on their basis. The only exceptions were age and weekly training frequency. However, the effect sizes were small in both cases.

Key words: orthorexia nervosa, climbing, prevalence

Introduction

Climbing is an umbrella term covering a broad spectrum of activities going in for different geographical environments (from indoor gyms to high mountains), various surfaces (rock, ice, artificial holding, etc.), formations of varying heights (from several-meter boulders to walls of several hundred meters long) or various fitness requirements for those practising them (strength and power in bouldering, long-term aerobic endurance in big wall climbing etc.). Although the common denominator of all forms of climbing is movement in the third dimension, figuratively referred to as 'fighting gravity', this is particularly true in rock climbing and sport climbing, which have been the most popular forms of climbing for many years (Michael et al., 2019; Gibson-Smith et al., 2020). The antigravitational nature of the climbing activity means that a low body mass, leanness, and a high strength/power-to-mass ratio are important determinants of success, especially at an advanced level (Joubert et al., 2022).

In the pursuit of high strength-to-weight values, rock and sport climbers, almost from the dawn of the sport, have resorted to low-calorie, often restrictive diets, carrying with them the risk of eating disorders such as anorexia and bulimia.

Although issues related to the extent of these problems in the climbing community for a long time did not go beyond anecdotal reports circulating in the climbing community and the pages of the trade press recognizing their seriousness, the IFSC (International Federation of Sport Climbing) in 2006 introduced a Body Mass Index (BMI) screening program at sport climbing competitions, at first sporadically and from 2021 regularly. However, this does not change the fact that the data available in the scientific literature are scarce. One of the few studies was conducted by Joubert et al. (2020), who, based on the results of the Eating Attitudes Test-26, diagnosed eating disorders in 6.3% of male climbers and 16.5% of female climbers. However, this tool was developed to capture individuals at high risk of anorexia in the population, so it is questionable to what extent it can diagnose other eating disorders, the diagnosis of which requires other tools (Jeacocke et al., 2018). The latter is important because eating disorders can take many forms. Anorexia and bulimia are among the most well-known to the broader public and most commonly discussed in the climbers' community. Both of the above-mentioned disorders fall into the category of so-called "specific" eating disorders, the diagnostic criteria for which are included in the DSM-5. In recent years, however, eating disorders with atypical symptoms have been recognised, for which the term non-specific eating disorders has been adopted, and the ICD-11 classification of diseases places them in the category of "other" eating disorders (Haman et al., 2015). One of them is orthorexia nervosa (ON) defined as: a "pathological focus on healthy eating with the features of rigorous attention to food quality and preparation and nutrition standards" (Turner & Lefevre, 2017). According to Varga et al. (2000), ON can be treated as a psychiatric disorder because the affected person loses objectivity with regard to a healthy lifestyle and diet, and although the choices made are socially recognised as healthy, they are exaggerated and radical (Varga et al., 2014). The affected person feels a sense of control over his or her life by maintaining a strict diet, which despite being centered on the quality of meals and searching for better foods, can result in nutrient deficiencies (Dittfeld et al., 2013; Brytek-Matera, 2019).

The estimated prevalence of ON in the general population is 1–7% (depending on the adopted measurement method) (de Souza & Rodrigues, 2014; Barthels et al., 2015; Koven & Abry, 2015; Rudolph et al., 2017; Dunn et al., 2017; Chard et al., 2018; Niedzielski & Kaźmierczak-Wojtaś, 2021), and in particular risk groups (athletes, yogis, appearance-conscious people) the risk can increase to 60% and even 90% (Michalska et al., 2016; McComb & Mills, 2019). Although unlike people affected by specific eating disorders, such as anorexia, orthorexics do not obsessively want to maintain a slim figure – with climbers, at least not for the sake of it – any deviation from a "healthy diet" results in an unfounded health fear (Dell'Osso et al., 2016). Since the studies of eating disorders in the climbing community undertaken to date, have not diagnosed the problem of ON, the study aimed to identify the extent of this phenomenon in climbers, considering the different variations of this activity. It also attempted to find an answer to whether the phenomenon of orthorexia in the climbing community depends on gender and whether the level of climbing impacts the occurrence of this disorder.

Material and methods

Participants

A total of 236 climbers (including 159 men and 77 women, 67.4 and 32.6%, respectively), with an average age of 34.7 ±9.2 years agreed to participate in the survey. For a more detailed description of the participants, see Table 1. Due to the highly dispersed nature of the climbing community only marginally concentrated in the formal structures of sports clubs, convenience sampling was used as the method for selecting the subjects. Climbers were recruited via the most popular climbing social media, where an invitation to participate in the study was posted. The study was designed in accordance with the deontological standards recognised by the Declaration of Helsinki. Study participants were assured that no personal information would be collected and identified. Before starting the process of answering the questionnaire, respondents were informed about the purpose of the study, the method of data collection and how the data would be used in the analyses.

Table 1. Characteristics of participants of the study (n = 236)

Variable	n	%
Gender		
Female	159	67.4
Male	77	32.6
Preferred kind of climbing		
Bouldering	58	24.6
Lead	174	73.7
Speed climbing	4	1.7
Competitive climbing		
No	162	68.6
Yes	74	31.4
Preferred terrain		
Gym climbing	65	27.5
Rock climbing	62	26.3
Gym and rock (season dependent)	109	46.2
Preferred climbing style		
Flash	24	10.2
OS	85	25.8
RP	156	30.1
None	236	33.9
Training experience (yrs)		
0–1	21	8.9
1–2	95	13.1
3–4	64	18.2
5–6	35	14.8
Over 6	201	44.9

Measures

The 10-item Polish version of Dusseldorf Orthorexia Scale (PL-DOS) (Brytek-Matera, 2020) was used for this study. The scale consists of 10 questions scored on a Likert scale from “this does not apply to me” (1 point) to “this applies to me” (4 points). The higher the result, the higher risk of orthorexic behaviour, and the cut-off points are 30+

pts for ON and 25–29 pts for risk of ON. The scale's reliability as assessed by the Cronbach's alpha formula was 0.82, indicating good internal consistency.

Statistical analysis

Descriptive statistics (means and standard deviations, numbers and percentage rates) were used to describe the data. To assess the significance of differences between variables Pearson's $\chi 2$ or $\chi 2$ with the Yates correction was used. The latter, if at least one of the expected frequencies was less than 5. The effect size of the Chi-square test was determined by calculating Cramer's V for contingency tables larger than 2 x 2. It was assumed that value under 0.30 means small effect size (weak association between variables), between 0.30 and 0.50 medium effect size (moderate association), and above 0.50 large effect size (strong association) (Speed & Andersen 2000). Data analysis was performed using Statistica 13.3 software (TIBCO Software, Inc.).

Results

Climbing preferences of the sample

Almost a third of the climbers (31.4%) surveyed take part in direct competition at climbing events, while the rest limit their activities to collecting lists of passages, being only a form of indirect or symbolic competition. Considering the preference of climbing competitions with which the study was most strongly identified, leading was dominant, followed by bouldering in second place (73.7 vs. 24.6%). Only a few people declared a focus on speed, which reflects the relatively low popularity of this kind of event in the climbing community. The average climbing experience of the study group was 5.1 ±1.2 years. The most frequently declared frequency of training was three to four times a week (n = 129, 54.7%), roughly a third trained 1–2 times a week (n = 90, 38.1%), a dozen people declared over five days a week (n = 17, 7.2%), training for an average of 2.3 ±0.7 hours at a time, with the shortest workouts completed by the least frequent climbers (2.1 ±0.7 hours) and the longest by those training most frequently (3.0 ±1.2 hours).

Evaluation of orthorexia in climbers

According to the classifications recommended for the DOS ON was diagnosed in 12.7% (n = 30) of climbers, with a mean score of PL-DOS scale of 32.8 ±2.4 with a 95% confidence interval ranging from 31.9 to 33.7. The ON risk was observed among 25.0% of the total sample (mean ±SD 26.8 ±1.5, 95% CI 36.4–27.2). Despite the relatively higher proportion of women in the orthorexia risk group, the difference between the both genders was not statistically significant. Similarly, there were no statistically significant differences with respect to the other variables. The only variables that were significantly associated with PL-DOS scores were training frequency ($\chi^2 = 13.35$, $p = 0.038$) and age ($F_{(1,234)} = 4.05$, $p = 0{,}045$). With regard to the former variable, the percentage of people with ON increased as the frequency of undertaking training increased. Age correlated negatively with PL-DOS scores ($\beta = -0.13$, $b = -0.02$), suggesting that the disorder is more likely to be present in younger climbers, although given the low value of the coefficient of determination the relationship is weak ($R^2 = 0.02$). Detailed data in Table 2.

Table 2. Prevalence of orthorexia in the climbing population

	ON	ON Risk	No ON	
Total sample	30 (12.7%)	59 (25.0%)	147 (62.3%)	
Gender				
Male	21 (13.2%)	34 (21.4%)	104 (65.4%)	$\chi^2 = 3.41$, p = 0.182, Cramer's V = 0.12
Female	9 (11.7%)	25 (32.5%)	43 (55.8%)	
Event				
Bouldering	5 (8.6%)	14 (24.1%)	39 (67.2%)	$\chi^2 = 2.69$, p = 0.715*, Cramer's V = 0.07
Lead	25 (14.4%)	44 (74.6%)	105 (71.4%)	
Speed	0 (0.0%)	1 (25.0%)	3 (75.0%)	
Competiton				
No	17 (10.5%)	43 (26.5%)	102 (63.0%)	$\chi^2 = 2.53$, p = 0.282, Cramer's V = 0.10
Yes	13 (17.6%)	16 (21.6%)	45 (60.8%)	
Terrain				
Gyms	6 (20.0%)	14 (23.7%)	45 (30.6%)	
Rocks	9 (30.0%)	16 (27.1%)	37 (26.2%)	$\chi^2 = 2.01$, p = 0.734, Cramer's V = 0.07
Gyms and rocks	15 (50.0%)	29 (49.2%)	65 (44.2%)	
Frequency				
1–2/wk	7 (7.8%)	25 (27.8%)	58 (64.4%)	
3–4/wk	16 (12.4%)	32 (24.8%)	81 (62.8%)	$\chi^2 = 13.35$, p = 0.038*, Cramer's V = 0.19
5–6/wk	4 (33.3%)	2 (16.7%)	6 (50.0%)	
Everyday	3 (60.0%)	0 (0.0%)	2 (40.0%)	

* because of the small expected frequencies in several table cells, chi^2 with Yates correction was used

Discussion

The study aimed to diagnose the prevalence of ON in the climbing community, taking into account potential variation in the risk of this disorder due to demographic variables, preferred types and styles of climbing and frequency of training. Despite many studies on the extent of ON in different populations (Håman et al., 2015, Niedzielski & Kazimierczak-Wojtas, 2021), including those undertaking different forms of physical activity and different sports (Segura-Garzia et al., 2012, Paludo et al. 2022, Hafstad et al., 2023), it has not been recognized among climbers to date. Therefore, to the best of our knowledge, this study was the first to address ON among climbers. Because of the importance of low body weight, the sport has traditionally been considered a risk factor for developing eating disorders, such as anorexia and bulimia. The emergence and development of bouldering as one of the climbing competitions, as well as the shift with much of the climbing activity from vertical walls to overhanging walls, has increased the importance of such motor skills as strength, power, power endurance, reducing the importance of low body weight per se. What has not changed, however, is the interest of climbers in diet and nutrition as a way to optimise the effects of their training. However, by following the principles of healthy eating, it is possible to cross the line beyond which they become morbid.

In the study sample of climbers, the proposed DOS cut-off points gave an incidence rate of 6.9% ON and 25% for ON risk. This rate is much lower than that found by Hafstad et al. (2023), who, based on a review of 24 studies of athletes representing a variety of individual and team sports, estimated the extent of orthorexia in these settings at 55.3%. It should be noted, however, that data on the prevalence of ON vary widely, ranging from a few per cent to, as reported by Hyrnik et al. (2021), as high as nearly 90% among yogis. The variability in the prevalence of various eating disorders in different populations is not unusual, as it is influenced by factors such as values shared in

specific communities, different worldview assumptions, different lifestyle awareness etc. However, prevalence estimates of ON are also influenced by factors related to diagnostic tools. In a study of Spanish students, Parra-Fernández et al. (2019) estimated the ON prevalence at 10.5% or 25.2%, depending on whether the diagnostic tool was the DOS or ORTO=11, respectively. With regard to the latter tool – the ORTO-15 version – estimates of ON prevalence depend on the cut-off level adopted, as found by Paludo et al. (2022). The prevalence of ON in the general population, assessed with the DOS, was usually a few per cent (Greetfeld et al., 2020; Brytek-Matera, 2021). Estimates of the extent of ON in exercise populations were also within these limits. For example, Rudolph (2018) diagnosed ON (DOS score of 30+) in 3.4% of fitness club exercisers.

The risk factors in our study were only two variables – age and frequency of training per week, but in the former case, this factor explained only 2% of the variation in the orthorexia scale score. So while the results suggest that younger climbers may be more prone to ON, the relationship between age and the behaviours in question is unlikely to be of practical significance. As for the second relationship mentioned above, one can see increasing percentages of climbers diagnosed with ON in groups with increasing training frequency per week. The latter reflects a commitment to climbing; and is related not only to training volume and intensity but also to other behaviours, especially dietary. The moderate effect size shows that the relationship between the variables is discernible. However, given the small number of people in the groups who train almost daily or every day, caution should be taken in drawing more definitive conclusions. It is an essential question for further research, as training involvement is most visible to the social environment (coaches, wall managers, fellow climbers, training partners) and thus show those who may be at higher risk of ON.

To the best of our knowledge, this study is the first to evaluate climbers in terms of ON. However, it has several limitations that should be mentioned. First, the convenient sample does not allow generalizing the results to the entire population of climbers. However, it should be emphasized that it is difficult to determine such representativeness because it is difficult to determine the size of the climbers' population and its characteristics, because most of these people are not associated in formal sports associations and clubs. Another area for improvement is the division we have adopted into preferred forms or types of climbing. Respondents declared which is their exclusive or primary form to which they devote themselves, which, on the one hand, is not always clearly definable and, on the other hand, carries the typical risks of self-description. In future research, it would be worthwhile to carry out separate diagnoses for climbers specialising in particular competition events (lead, speed, bouldering) and separate diagnoses for climbers pursuing their goals in rock climbing, divided into recreational and high-performance levels. Also, ON is a relatively new disorder with an incompletely clarified status regarding uniform and operationalized diagnostic criteria and reliable assessment tools. The measurement scales developed to date are characterized by different psychometric properties, which makes it difficult to assess the ON phenomenon, both to compare the results of different studies and in terms of precisely defining the boundary between a far-fetched interest in healthy eating and a disorder that can lead to actual disruptions in functioning. Some studies confirm that ON is associated with weight control motives, compulsive exercise and negative food motivations (Mavrandrea & Gonidakis et al., 2022; Foyster et al., 2023). However, even if the boundaries between the two spheres are blurred, it is crucial to monitor the situation, especially in communities that appear to be at risk of crossing these boundaries. Climbing practitioners are among such communities, so further research involving larger study samples is needed. Climbers should be made aware of the importance of a balanced diet and the dangers of not only extreme dietary restrictions, but also excessive indulgence in 'healthy eating'. Climbing coaches and climbing section leaders should educate

their mentees that while the pursuit of a healthy diet is generally positive and will help to achieve training goals, an extreme focus on cleanliness and food quality can have negative health consequences and, in retrospect, limit one's potential to develop as a climber.

Conclusion

Overall, these findings highlight the need for awareness of ON and its potential consequences in the climbing community. Education on healthy nutrition practices tailored to this population may help prevent disordered eating from developing. Further research is warranted to explore potential risk factors and effective prevention and intervention strategies tailored specifically to climbers.

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THE EFFECTS OF TRAINING WITH ADDITIONAL WEIGHT SHORTS ON PHYSICAL PERFORMANCE OF ADOLESCENT SOCCER PLAYERS

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Abstract This study examined the effects of an on field combined strength/speed/soccer training program on the physical performance of 20 male adolescent (age: 14.0 ±0.7 years) soccer players, who were divided into an experimental and a control group (EG, CG). The EG players wore "weight shorts", with 300 gr of additional weight on each thigh and participated 2 times/week in a 12-week training intervention program. The CG followed the same training program without wearing the "weight shorts". The physical abilities were evaluated the week before (pre) and two days after the 12-week intervention training period (post) and the follow-up evaluation was performed 4 weeks after the post measurement. The measured parameters were: a) sprint/repeated sprint ability (straight and with 180° turns, RSA-best/mean/total), b) RSA fatigue-index, c) vertical jump ability and d) lower body maximal strength. The EG improved significantly more ($p < 0.05$) compared to the CG on 10-m-straight, 30-, 35-, 40-m with 180° turns RSAbest-sprints, RSA fatigue-index, squat jump, leg curl (single right/left leg) and in split squat (single right/left leg) 5RM load. Using special shorts with additional weights on the thighs during soccer training improved speed/RSAbest-times and fatigue-index, jump ability and lower limbs maximal strength in youth soccer players.

Key words: youth, lower limbs, speed, strength, power

Introduction

Soccer is a sport of intermittent efforts, in which sudden variations in both the intensity of the game and the type of actions or motor tasks occur continuously (Cossio-Bolaños et al., 2021). During the game on average, every 2 to 4 seconds, soccer players perform a total of 1200–1400 of intensive actions (Škomrlj et al., 2022). Typical soccer movements such as tackling, jumping, sprinting, shooting, and rapid change-of-directions (COD) require high levels of physical fitness and they are crucial for optimal performance not only in adult but also in youth soccer (Zghal et al., 2019). In various youth age groups, including 13–18 years (Murtagh et al., 2018), it has been shown that strength, jump and sprint performances clearly differentiate between elite and sub-elite youth level soccer players (Stewart et al., 2014). Developing a high level of muscular strength is a decisive goal in preparing for competition as stronger soccer players perform better (Fischerova et al., 2021) and are more resilient to fatigue, possess greater capacity to preserve power output at a given intensity and greater repeated sprint ability (RSA) tasks (Yu et al., 2020). Especially the lower-limb muscles play a crucial role, and are mostly used during jumps, sprints, changes of direction and kicks (Beato et al., 2021). Thus, soccer players must both manage technical and tactical tasks and use appropriate strength training programs which could enhance several explosive actions that are crucial to the result of the game (Rodriguez-Rosel et al., 2017).

Previous studies were conducted to enhance athletic performance in youth soccer players with several types of strength training (e.g., machine based, free weight or combined, plyometric/complex/functional training), training periods, intensities, volumes and exercise choices. Some of them demonstrated positive findings of general and soccer-specific performance and others not (Granacher et al., 2016). Among them, some studies applied resistance training additionally to soccer training (Christou et al., 2006), plyometric exercises into the regular soccer training (Negra et al., 2018), complex training (combining resistance and plyometric training) additionally to regular soccer training (Hammami et al., 2017) and only one study applied strength training by performing specific soccer movements with additional weight during regular soccer training (Bogiatzidis et al., 2022). In the above studies, some significant differences were observed between the experimental and control groups, specifically in maximal strength of the upper and/or the lower body (Christou et al., 2006; Bogiatzidis et al., 2022), in sprint times during 5- to 40- meters and in RSA (Hammami et al., 2017; Negra et al., 2018), in vertical jump height (CMJ, SJ or DJ) (Christou et al., 2006; Negra et al., 2018; Bogiatzidis et al., 2022) and in agility (Christou et al., 2006; Hammami et al., 2017).

Strength training must be integrated into sport skills training (Hammami et al., 2017) to enhance motor performance and to reduce the risk of sports related injuries. Thus, youth athletes may benefit from implementing muscular fitness enhancing exercises in their regular training (Granacher et al., 2016). In this context, training equipment which could be used by any team and is portable and relatively inexpensive can provide positive training effects. As far as we know, only one study has examined the effects of an on-field strength training for the lower limbs on adolescents using portable wearable training equipment such as additional weights on the thighs into regular soccer training (Bogiatzidis et al., 2022). The current study is the evolution based on this previous pilot study and the purpose was to examine the effects of an on-field lower limbs' combined strength and speed/soccer training program into regular soccer training using portable wearable equipment on physical performance of youth soccer players. It was hypothesized that taking part for 12 weeks in targeted speed/soccer training sessions, while wearing special-construction Additional Weight Shorts (AWS) with 300 gr on each thigh as strength load, would improve speed, RSA performance, maximal strength and jump ability of youth soccer players.

Methods

Participants

Twenty male regional soccer players, aged 14.0 ±0.7 years, voluntarily participated in the current study. The players and their parents were informed about the nature and the aim of the study, its benefits and risks. Afterwards, the parents signed an informed consent form which was approved by the University's institutional review board and ethics committee. All the procedures were in accordance with the Declaration of Helsinki. The participants were randomly separated into an experimental group (EG; N = 10) and a control group (CG; N = 10) (Table 1).

Table 1. Mean and standard deviation of the participants' characteristics before the intervention

	Experimental Group (N = 10)	Control Group (N = 10)
Age (years)	14.1 ± 0.7	13.8 ± 0.8
Training Age (years)	7.0 ± 2.7	5.8 ± 3.5
Height (m)	1.72 ± 0.08	1.73 ± 0.06
Weight (kg)	64.1 ± 12.8	64.3 ± 8.14
BMI (kg/m^2)	21.45 ± 2.92	21.38 ± 2.21
Waist Circumference (cm)	70.50 ± 6.25	71.50 ± 5.48
Dominant Leg Right/Left	8/2	8/2

No group differences were significant ($p > 0.05$). BMI = body mass index

Training program

The soccer players from both groups (EG, CG) were trained together as one team, 4 times per week (Monday, Tuesday, Wednesday and Thursday). They participated in exactly the same training sessions during the 12-week intervention program on a soccer field with natural grass. The only difference between the two training groups was that the EG players wore in each training-intervention session (Tuesday and Thursday) special shorts designed by the researchers and constructed exclusively for the purposes of the current study, the Additional Weight Shorts (AWS). In these shorts, the additional weight for each leg was 300 gr which was used as strength load (Figure 1a). The additional weight was added in a special socket at the height of the thighs (Figures 1b and 1c). The soccer players wearing the AWS (Figure 1d) were able to run, jump, pass, shoot and take part in overall soccer training without any discomfort. To fit each participant well, there were different sizes (XL youth-size, S-L adult-sizes) of shorts.



Figure 1. (a) Additional weight case of 300 gr. (b, c) Socket for the additional weight. (d) Additional Weight Shorts (AWS). (Photographs: Efthimios Bogiatzidis)

Each training session lasted 90 min and the aim was to improve the soccer players' technical, tactical and physical performance. Each standard training-intervention session consisted of – warm-up: 25 min (running, stretching, rondo games i.e., 5vs2), – main part: 20–30 min intervention program, 25–35 min soccer training e.g. practice games with goals (large or small) for retaining possession and passing the ball as a group, small side games, multiple actions or games with tactic elements/guided games, and final games (e.g. free play, freedom of expression, spontaneity, creativity), – cool down: 10 min (5 min recovery-leisurely running and 5 min stretching). No other strength or speed exercises were performed in the standard training sessions on Monday and Wednesday (technical/tactical training the same for all participants), except for those in the intervention program, which were integrated into standard training twice per week on Tuesday and Thursday and consisted of four exercises. Table 2 presents the training contents applied throughout the 12-week intervention program which is quantified in table 3. The exercises used in the intervention program were chosen for improving the soccer players' performance through competitive training mainly with the ball, because they simulate the soccer match. They were specific soccer-related exercises (speed/strength/power, individual/subgroup tactics), which contained accelerations-decelerations, 15–30 m sprints, changes of direction, vertical jumps, 1vs1 and 2vs2 actions. The training load of the intervention program was progressively increased from 1st week-12th week as shown in Table 3. In addition, during the 12 weeks of training all participants took part in 6 official regional soccer-matches on Saturday, lasting 80 minutes (2 × 40 minutes/half). To ensure an equal participation time of all soccer players in these matches, they were divided into 2 subgroups (group A and B), in each of which 5 soccer players who wore the AWS participated. All participants started the matches and played with a mean duration of 60 ±5 min in the matches. On the remaining 6 Saturdays without a match, training took place in 3 of them with same contents for all soccer players (technical/tactical training) and in the other 3 they had a free day.

Table 2. Training contents applied throughout the 12-week intervention program

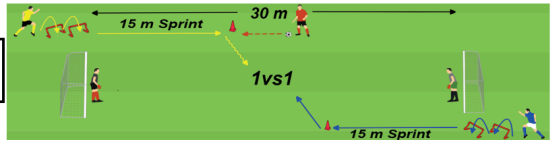
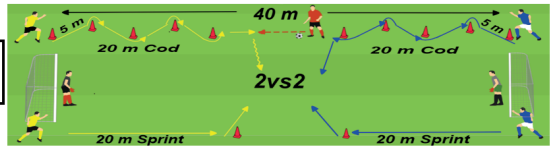
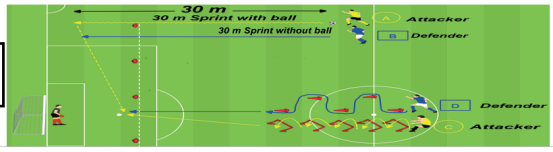
Exercise a and a*		Exercise a: Knee lifts with 300 gr on each thigh Exercise a*: Knee lifts with 600 gr on each thigh
Exercise b		Players from both sides perform 2x 45 cm hurdle jumps, then 15-m straight sprint with ball receiving from one side (attacker) and try 1vs1 to score against the defender
Exercise c		Players from both sides perform straight sprints and cods each 20-m, then receiving the ball from one side (attackers) and try 2vs2 to score against the defenders
Exercise d		Attacker A with ball, defender B without (3 sec later) are starting a 30-m straight sprint. Attacker C jumps 5x 45 cm hurdles and receiving attacker 's A pass trying to score, defender D performs 5x cods and prevent C to score. Then all players sprint 15-m back to marked line

Table 3. Training program during the 12-week intervention traing period

	Week 1		Week 2		Week 3	Week 4		
Exer	Ses 1	Ses 2	Ses 3	Ses 4	Ses 5	Ses 6	Ses 7	Ses 8
a)	10 × 2	10 × 2	10 × 3	10 × 3	–	10 × 3	–	10 × 3
a*)	–	–	–	–	10 × 3	-	10 × 3	–
b)	× 4 (2 + 2)	–	× 6 (3 + 3)	–	× 6 (3 + 3)	-	× 8 (4 + 4)	–
c)	× 4 (2 + 2)	–	× 4 (2 + 2)	–	× 6 (3 + 3)	-	× 6 (3 + 3)	–
d)	–	× 2	–	× 3	–	× 3	–	× 3

	Week 5		Week 6		Week 7	Week 8		
Exer	Ses 9	Ses 10	Ses 11	Ses 12	Ses 13	Ses 14	Ses 15	Ses 16
a)	–	10 × 3	–	10 × 3	–	10 × 3	-	10 × 3
a*)	10 × 3	–	10 × 3	–	10 × 3	–	10 × 3	–
b)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
c)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
d)	–	× 3	–	× 3	–	× 3	–	× 3

	Week 9		Week 10		Week 11	Week 12		
Exer	Ses 17	Ses 18	Ses 19	Ses 20	Ses 21	Ses 22	Ses 23	Ses 24
a)	–	10 × 3	–	10 × 3	–	10 × 3	–	10 × 3
a*)	10 × 3	–	10 × 3	–	10 × 3	–	10 × 3	–
b)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
c)	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–	× 8 (4 + 4)	–
d)	–	× 3	–	× 3	–	× 3	–	× 3

All repetitions were separated by work to rest ratio 1/5. Work 10 sec/rest 50 sec (exercises a, a*, b) and work 20 sec/rest 100 sec (exercises c, d). Between exercises 100 sec rest. After 8 weeks in exercise d 20-m sprint back

Testing procedures

The physical abilities were evaluated the week before (pre) and two days after the 12-week intervention training period (post) and the follow-up evaluation was performed 4 weeks after the post measurement.

The tests were executed at an outdoor soccer field with natural grass, where the participants wore soccer shoes, and at a gym with fitness equipment, where they wore indoor shoes. The week before testing there was a familiarization with the execution of the physical ability tests and proper form and technique of each test was practiced according to the instructions of the research assistants. Before testing, the soccer players abstained from physical exercise for 1 day. Verbal encouragement was used throughout all tests to achieve maximum effort. The same researcher measured all the participants.

Sprint and Repeated Sprint Ability (RSA) testing: 40-meters (20 + 20-m) of six shuttle sprints time was measured with 3 paired photocells using the Witty Microgate (Bolzano, Italy), which began with a standardized warm-up of 20 minutes. A photocell was placed at the start, at 5- and 10-m at a height of 90 cm from the ground. The player started from a standing position 50 cm from the first photocell to avoid an early activation of the timing mechanism, sprinted for 20-m, touched a line with a foot, turned 180º and came back to the starting photocell as fast as possible. After 20 sec of passive rest, the soccer player started again. Five seconds before the start of each sprint, the player assumed the ready position and was given a 5-sec countdown to an acoustic start signal (Rampinini et al., 2007). Immediately after the warm-up, players completed a practice single shuttle sprint and rested for 5 minutes before starting the definitive test. The best time in a single trial (RSAbest) in straight sprint at 5- and 10-m, with 180º turns in sprint at 30- (20 + 10-m), 35- (20 + 15-m) and 40-m (20 + 20-m), the mean and total times all of them (RSAmean, RSAtotal) were recorded and the 6 × 40m (20 + 20-m) fatigue-index (RSAfatigue-index) was calculated according to the formula: Fatigue = ([Slowest two sprint times ÷ 2] – [fastest two sprint times ÷ 2]) ÷ ([fastest two sprint times ÷ 2]) × 100 (Glaister et al., 2008) and used for further analysis.

Vertical jump performance: Vertical jump ability was assessed using the squat jump (SJ), the countermovement jump (CMJ) and the drop jump (DJ). Vertical jump height (SJ, CMJ, DJ) time contact and power (DJ) were assessed using an optical measurement system consisting of a transmitting and receiving bar (Optojump Microgate. Bolzano, Italy). For the execution of the SJ, the participant placed his feet in the area between the bars with the arms akimbo, adopted the semi-squat position (knees angle at 90°) and without any pre-stretch performed a maximal vertical jump. The researcher was taking care that the participant was descending at each jump until a knee angle of 90° was formed, landing with the toes and approximately in the same area between the bars. For the CMJ, each participant placed his feet in the area between the bars and his body was in an upright position with the arms akimbo. The participant moved from an upright position down to a semi-squat and performed a maximal vertical jump (stretching-shortening cycle), taking care to land on approximately in the same area between the bars with the legs kept outstretched during the jump. For the DJ, 40 cm drop height was used. The participant stood on top of the box with his arms akimbo, took one step forward with the leading leg straight to ensure a drop height of 40 cm and dropped in the area between the bars with both legs on the ground with a short and powerful contact extending the ankles and performed a vertical jump, without bending the knees and landed likewise in an extended position in the same area between the bars. The average value of the 3 trials of each test was used for further analysis, with one minute of rest between the 3 trials of each test.

Maximum strength: Maximum strength of the lower limbs was measured with single right and left leg in the exercises leg curl and split squat. As an index of maximum strength, the maximum load that could be lifted for

5 repetitions (5RM load) in each exercise was considered. As a warm-up, one set of 8 repetitions was performed with a 50% load of the estimated 5RM load, and one set of 5 repetitions with a 75% load of which the estimated 5RM load were executed. After those 5 repetitions with the load estimated to be the 5RM load, attempts were performed. If the trial was successful, the load was increased by 10% until the participant was unable to successfully perform 5 repetitions, which occurred within two to four trials. The rest interval between sets was 3 minutes.

Leg curl testing was performed on a leg curl machine (Super Sport, Athens, Greece) with the participant lying face down, the hands grasping handles and performing a single right/left full knee flexion.

The split squat testing was executed using a smith machine (Sfitness, Shanghai, China). The test started with the participant standing upright on one leg. The top of the leg which did not participate in the movement was placed on a standard gym bench, positioned behind the participant, to ensure that the working leg was isolated to perform the attempt. The participant had to execute a single right/left-leg squat until a 90° angle was formed between the thigh and the shank.

Statistical analysis

The normal distribution criterion was satisfied after contacting the Shapiro-Wilk test. Two-Way Repeated measures ANOVAs were used for the statistical treatment of the data, with "Group" as between and "Time" as within factor, along with the post hoc test Bonferroni, except Drop Jump time contact, in which Two-Way Ancova Repeated measures were used. The statistically significant level was set as $p < 0.05$. All results are reported as mean ±SD.

Results

Twenty participants successfully completed the study without reporting any injury during the intervention or the overall soccer training program. Before the intervention program, the two groups (EG, CG) did not differ significantly (all, $p > 0.05$) regarding chronological age, training age (i.e., training background) and their anthropometric characteristics. After the 12-week intervention program, significant interactions were revealed between the two factors ("Group" and "Time"). The EG showed statistically significant improvements compared to the CG in 10-m-straight [$F_{(2,36)} = 3.612$; $p = 0.037$], with 180º turns in 30-m (20 + 10-m) [$F_{(2,36)} = 3.296$; $p = 0.048$], 35-m (20 + 15-m) [$F_{(2,36)} = 4.158$; $p = 0.024$] and 40-m (20 + 20-m) [$F_{(2,36)} = 4.396$; $p = 0.020$] RSAbest-sprints, in RSAfatigue-index [$F_{(2,36)} = 3.573$; $p = 0.038$], in Squat Jump height [$F_{(2,36)} = 3.393$; $p = 0.045$], in Drop Jump time contact [$F_{(1,17)} = 6.054$; $p = 0.025$], in Leg Curl single right and left leg [$F_{(2,36)} = 5.004$; $p = 0.012$], [$F_{(2,36)} = 5.842$; $p = 0.006$], in Split Squat single right and left leg [$F_{(2,36)} = 11.928$; $p = 0.000$], [$F_{(2,36)} = 15.569$; $p = 0.000$] with no significant differences in all above variables between the two groups, except in RSAfatigue-index in the post intervention measurement [$F_{(1,18)} = 14.715$; $p = 0.001$], in Drop Jump time contact in the follow up measurement [$F_{(1,17)} = 9.798$; $p = 0.006$], in Split Squat single right leg in the follow up measurement [$F_{(1,18)} = 12.949$; $p = 0.002$] and in Split Squat single left leg in the post measurement [$F_{(1,18)} = 4.934$; $p = 0.039$] and follow up measurement [$F_{(1,18)} = 16.514$; $p = 0.001$].

A significant simple main effect of the within factor "Time" was observed only in the EG in 10-m-straight [$F_{(2,17)} = 11.795$; $p = 0.001$], with 180º turns in 30-m (20 + 10-m) [$F_{(2,17)} = 12.717$; $p = 0.000$], 35-m (20 + 15-m) [$F_{(2,17)} = 16.936$; $p = 0.000$] and 40-m (20 + 20-m) [$F_{(2,17)} = 16.325$; $p = 0.000$] RSAbest-sprints, in Squat Jump height [$F_{(2,17)} = 15.400$; $p = 0.000$] and in Drop Jump time contact [$F_{(1,17)} = 9.953$; $p = 0.006$]. The post hoc Bonferroni test revealed significant differences between the post intervention and the follow up measurement in 10-m best straight-sprint, between the pre intervention and the follow up measurement and between the post intervention and

the follow up measurement with 180º turns in 30-m (20 + 10-m), 35-m (20 + 15-m) and 40-m (20 + 20-m) RSAbest-sprints, between all measurements. No significant differences between the post intervention and the follow up measurement on Squat jump height and between the pre intervention and the follow up measurement in Drop Jump time contact were observed (Table 4).

A significant simple main effect of the within factor "Time" was observed in both groups in Leg Curl single right leg EG: [$F_{(2,17)}$ = 24.550; p = 0.000], CG: [$F_{(2,17)}$ = 6.589; p = 0.008], in Leg Curl single left leg EG: [$F_{(2,17)}$ = 26.666; p = 0.000], CG: [$F_{(2,17)}$ = 6.677; p = 0.007], in Split Squat single right leg EG: [$F_{(2,17)}$ = 43.336; p = 0.000], CG: [$F_{(2,17)}$ = 7.388; p = 0.005] and in Split Squat single left leg EG: [$F_{(2,17)}$ = 59.000; p = 0.000], CG: [$F_{(2,17)}$ = 9.678; p = 0.002]. However, in all the above variables in the EG, the post hoc Bonferroni test revealed significant differences between all measurements, while in the CG, significant differences were found between all measurements, except between the post intervention and the follow up measurements (Table 4).

A statistically significant main effect of the within factor "Time" was observed in 5-m best straight-sprint [$F_{(2,36)}$ = 4.333; p = 0.021], with 180º turns in 30-, 35- and 40-m RSAmean scores [$F_{(2,36)}$ = 6.507; p = 0.004], [$F_{(2,36)}$ = 8.297; p = 0.001], [$F_{(2,36)}$ = 8.828; p = 0.001], with 180º turns on 30-, 35- and 40-m RSAtotal scores [$F_{(2,36)}$= 6.524; p= 0.004], [$F_{(2,36)}$= 8.297; p= 0.001], [$F_{(2,36)}$= 8.828; p= 0.001], in CMJ [$F_{(2,36)}$ = 9.259; p = 0.001], in Drop Jump height [$F_{(2,36)}$ = 4.352; p = 0.020] and in Drop Jump power [$F_{(2,36)}$ = 7.847; p = 0.01] regardless of "Group". The post hoc Bonferroni test revealed significant differences between the post intervention and the follow up measurement in 5-m best straight-sprint between all measurements, except between the pre and the post intervention measurements with 180º turns in 30-, 35- and 40-m RSAmean and RSAtotal scores, and in CMJ, between the pre and the post intervention measurement in Drop Jump height and between all measurements, except between the post intervention and the follow up measurement in Drop Jump power. No significant differences were found in 5- and 10-m RSAmean and RSAtotal scores, neither between the two groups, nor between the pre, post intervention and follow up measurements.

Table 4. Mean and SD values of the pre-intervention, after 12 weeks of the training intervention, and after a 4 week follow up period in the experimental and control groups

	Experimental Group (N=10)			Control Group (N=10)		
	Pre	Post	Follow up	Pre	Post	Follow up
10-m best straight sprint (s)	1.91 ± 0.05	1.94 ± 0.07	1.86 ± 0.06 #	1.91 ± 0.10	1.96 ± 0.11	1.94 ± 0.10
30-m (20+10m) best sprint (s)	6.14 ± 0.18	6.12 ± 0.21	5.95 ± 0.21 ^#	6.24 ± 0.40	6.21 ± 0.34	6.20 ± 0.34
35-m (20+15m) best sprint (s)	6.93 ± 0.20	6.90 ± 0.25	6.70 ± 0.24 ^#	7.05 ± 0.44	7.00 ± 0.42	6.98 ± 0.40
40-m (20+20m) best sprint (s)	7.70 ± 0.22	7.66 ± 0.29	7.44 ± 0.28 ^#	7.86 ± 0.54	7.82 ± 0.48	7.80 ± 0.48
RSAfatigue-index (%)	6.96 ± 2.77	5.39 ± 1.93 *	6.27 ± 1.95	7.79 ± 3.21	9.66 ± 2.94	8.07 ± 3.48
Squat Jump Height (cm)	22.55 ± 3.10	25.55 ± 4.52 ^	26.82 ± 3.87 ^	22.55 ± 4.81	23.66 ± 5.58	24.50 ± 5.55
Drop Jump T. Contact	0.207 ± 0.01 s	-2.70 ± 8.38 %	-10.54 ± 6.84 % ^*	0.228 ± 0.01 s	-6.21 ± 6.60 %	-4.83 ± 7.39 %
5RM Leg Curl Right-leg (kg)	17.40 ± 7.36	24.00 ± 9.47 ^	26.90 ± 11.52 ^#	17.30 ± 2.35	20.50 ± 3.53 ^	22.20 ± 3.76 ^
5RM Leg Curl Left-leg (kg)	16.80 ± 5.57	23.50 ± 7.92 ^	26.10 ± 9.55 ^#	16.00 ± 1.76	18.90 ± 2.92 ^	20.80 ± 2.86 ^
5RM Split Squat Right-leg (kg)	41.20 ± 11.16	60.20 ± 14.70 ^	77.10 ± 14.85 ^#*	41.60 ± 9.22	49.50 ± 7.94 ^	56.30 ± 10.65 ^
5RM Split Squat Left-leg (kg)	41.10 ± 10.00	59.10 ± 12.19 ^*	75.60 ± 11.47 ^#*	41.40 ± 8.72	48.90 ± 7.88 ^	54.90 ± 11.30 ^

* Significantly different from the control group
^ Significantly different in comparison with the pre-intervention measurement
# Significantly different in comparison with the post-intervention measurement

Discussion

This is the main study based on the previous pilot study (Bogiatzidis et al., 2022) and the aim was to examine the effects of using a specific strength training tool, weighted shorts with 300 gr on each thigh worn while participating in an on-field lower limbs combined strength/speed/soccer training program, on the development of physical performance of U-16 youth male soccer players. The main findings of the current study were that sprinting speed, RSA fatigue-index, strength of the lower limbs, the vertical jump ability (Squat Jump) and the Drop Jump time contact of the young soccer players were improved, while RSAmean and RSAtotal scores, the height of Countermovement Jump and the height and power of the Drop Jump were not affected.

Several contrasting findings were observed in the studies regarding the effectiveness of strength training on sprint performance. Studies that found no effect or even a negative effect were reported (Gorostiaga et al., 2004; Lopez-Segovia, et al., 2010; Bogiatzidis et al., 2022). The current findings are in agreement with studies that observed an improvement in sprint performance in youths of similar ages with our sample, following a standard strength or a combined strength training period. Hammami et al. (2017) observed an improvement in sprint times of 5-, 10-, 20-, 30- and 40-m in male soccer players, aged 16.0 ±0.5 years after an 8-week in-season intervention program, which used the back half squat as a training exercise before standard training sessions. Christou et al. (2006) showed a significant improvement in 30-m, but not in 10-m sprint time in male soccer players aged 13.8 ±0.4 years, after a 16-week strength training program twice a week, which included 10 machine based and free weight exercises (e.g., leg press, bench press, leg extension, pec-dec). In the current study the performance on straight 10-m best-sprint in the EG improved significantly compared to the CG but not in 5-m. It seems, that to improve the 5-m speed performance, a more targeted and specific program may be required, once in the current study the distances covered by the soccer players during the intervention were between 15-30 meters and longer. Regarding the other sprint/RSA distances, the EG improved significantly compared to the CG in RSAbest-sprints with 180° turns in 30- (20 + 10-m), 35- (20 + 15-m) and 40-m (20 + 20-m) and in RSAfatigue-index, while in RSAmean and RSAtotal scores revealed no differences between the two groups. As far as we know, no other study measured RSA scores in 5- and 10-m straight sprints, with 180° turns at 30- (20 + 10-m) and 35-m (20 + 15-m) in addition to 40-m (20 + 20-m). Therefore, there is an agreement only regarding RSAbest 40-m (20 + 20-m), but regarding the RSAtotal 40-m (20 + 20-m) and RSAfatigue-index parameters it is in disagreement with the findings in a previous study in prepuberal soccer players aged 12.7 ±0.2 years (Negra et al., 2018). Another study conducted in adolescent soccer players aged 16.0 ±0.5, revealed no significant differences in all RSA parameters (RSAbest/mean/total/fatigue-index) after 8-weeks of standard and contrast strength training (Hammami et al., 2017). Both of the above studies used the same RSA-test like our study. The lack of improvement in our study in RSAmean and RSAtotal scores can be logically explained. As it is shown and quantified in the intervention training program (Table 3), applying suitable and age-related training in our age-sample, the main goal was the improvement of speed-force parameters and not the improvement of sprint-speed endurance, that is anaerobic lactate capacity. This is also shown from the relation work-rest time, where the rest times were long. Therefore, no positive effects were revealed in the above RSA scores, although there seems to be a tendency to improvement.

However, our RSA test consisted of 6 shuttle sprints of 40-meters (20-m straight, turn 180° and again 20-m straight). That is, it also contained elements of changes of direction (COD). Improvements in COD after a strength training in similarly age groups with our study were reported (Hammami et al., 2017; Negra et al., 2018). Falces-Prieto et al. (2022) reported that linear sprinting speed may influence COD, while angle and entry velocity can also

constraint the COD performance. Additionally, body mass, lower limb power, and strength can also play important roles in COD performance. They confirmed in males aged 14.8 ±0.4 years, that jump performance and linear speed in 10-m were determinants of COD performance. Brughelli et al. (2008) stated that the training protocols reporting improvements in COD have utilized exercises that more closely mimic the demands of COD, which include sport-specific and general COD training. In our training program we included both straight-line speed and COD exercises.

In relation to power in the current study, the vertical jump ability measured by Squat Jump test improved significantly in the EG compared to the CG, but not in Countermovement Jump test. The explanation for this may be, that wearing the AWS in which the weights were placed on the thighs, this muscle unit was more affected, which mainly and actively participates in the execution of the Squat Jump and therefore contributed to the improvement of its performance in the EG. The execution of the Countermovement Jump requires the participation of all lower limb muscles and perhaps for this reason it was not improved. Similarly, with our findings reported Chelly et al. (2009) after an 8-week resistance training program, using the back half squat with 1-RM previously measured as a training exercise twice a week, immediately before the regular soccer training session. On the contrary, Bogiatzidis et al. (2022) reported in male soccer players aged 15 ±0.5 years significant improvement in the EG compared to the CG in the Countermovement Jump, but not in Squat Jump test after 12 weeks in-season training period. The soccer players of the EG used to wear like our intervention the AWS with additional weight of 300 gr on each thigh and the players of CG not. However, the EG and CG players participated normally in the soccer training sessions, without any specific target for improving any separately soccer ability/skill, and it seems that it has affected more the muscle units used in the Countermovement Jump. Regarding the Drop Jump test in our study, the EG improved significantly compared to the CG only in the ground contact time, but not in height and power. Keiner et al. (2018) using 32 cm Drop Jump height evaluated the effects of long-term (2 years) strength training on reactive strength in male adolescent soccer players aged U13-U16 years, using parallel squats (back/front), deadlift, upper extremity exercises (bench press, neck press, standing row and trunk muscle exercises) 2 times/week immediately before the regular soccer training session. The strength training group improved significantly compared to the control group in jump height but not in contact time over time. They reported that jump height is more affected by strength training than contact time and maybe a combination of both strength and reactive strength training is more effective in improving contact time than just strength training alone. In our study, we combined strength and plyometric jump exercises and it seems that they were effective in improving the ground contact time.

Regarding the strength performance in the current study, using the Leg Curl and the Split Squat (single right and single left leg) as training exercises with 5-RM load, the EG achieved a significantly higher performance compared to the CG in both exercises with the single right and single left leg. Bogiatzidis et al. (2022) reported no difference in improvement between the two groups in Leg Curl, but using the typical form of the Leg Curl (both legs) and in Split Squat single right/left leg, they reported a significant improvement in the EG performance compared to the CG only with the single left leg, but not with the single right leg.

In our study, we observed several improvements in the follow-up measurements after the end of the training period, although the EG-players did not wear the AWS during training for 4 weeks. Perhaps due to the physical adaptations that took place from the 12-week training period. Probably, to reveal the positive effects of this particular training method, a decreasing period of stress and training without additional load on the thighs was essential. Conversely, the improvement e.g., in Leg Curl and Split Squat single right/left leg of the CG may be due to the participants growth, because they were in adolescence but also from the soccer training participation alone that

leads to improvements in the lower body performance. According to this, Christou et al. (2006) showed in male soccer players aged 13.8 ±0.4 years, significant increases in lower-body strength (leg press) not only after 8 and 16 weeks of strength/soccer and soccer training but in the control group as well.

As far as we know, the current study is the first which examined the effects of a combined strength and speed/soccer training program using weighted shorts during regular soccer training on the improvement of physical performance of adolescent soccer players. The Additional Weight Shorts is: a) an easily added and removed portable wearable training tool, b) by wearing it, all soccer-specific movements can be executed, the soccer players can participate normally in all soccer training sessions, and the coaches have nothing to change in their planning, and c) no training-related injuries were reported, so it appears to be a safe alternative strength training tool.

However, there are limitations in our study. First of all, the small number of participants. A bigger sample could have provided better results about the effects of training with AWS on the physical performance of young soccer players. Also, our study consisted of only adolescent male soccer players limited to the specific U-16 age-group. Therefore, the results cannot be generalized to other developmental ages and gender. Furthermore, the results were based on the chronological rather than the biological age of the participants. We did not assess the maturity status before the study, and there may have been differences between participants, which could have affected the results of our study. Moreover, the improvements achieved in the present study are test-specific, meaning that the selection of different tests of physical abilities (other sprint tests or distances, lower-limbs measures etc.), training periods and intensities may have produced different results and correlations.

Therefore, further research should aim to include larger sample sizes, different age-groups, assessment of maturity status, and females as well as adults. Additionally, more field and laboratory tests and of course different training protocols should be included (using greater than 300 gr as strength load at each thigh or adding the strength load on other muscle parts like hamstrings etc.), to provide a more complete picture of the effects of these different strategies on physical performance of young soccer players.

In any case, this study is practically important, because it was applied on the field with a new and alternative strength training tool without disturbing the regular training sessions.

Conclusions

The current study revealed, as it was expected, that U-16 age male soccer players from both groups (EG, CG) who participated in the same 12-week strength/speed/soccer program showed improvement in some parameters of physical performance. However, the soccer players from the EG who wore the AWS during the training program improved their performance more compared to the CG in RSAbest-sprints (straight and with 180º turning), RSA fatigue-index, strength/power of the lower limbs and jump performance. Although, the results should be interpreted with caution. Firstly, due to the small sample size. Also, on the one hand, our findings showed that the greater improvements from the EG may have been caused by the progressively increased training load using the AWS, but on the other hand, at this age-stage some changes could also have happened due to the maturity. Furthermore, our results were based on the chronological and not on the biological age of the participants. However, our findings are encouraging and important to soccer coaches/scientists, because without additional time and changes in training using a practical, cheap and portable tool, this modality can be directly applied in practice for development and training of young soccer players.

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INFLUENCE OF LIVE HIGH TRAIN HIGH ON PHYSIOLOGICAL TRAINING ADAPTATIONS AND ATHLETIC PERFORMANCE IN TRAINED RUNNERS: AN OBSERVATIONAL COHORT CASE STUDY

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Abstract Introduction: Live high-train high (LHTH) is suggested to improve performance, especially maximal aerobic capacity through the hypoxic adaptation responses. The present study aims to determine the impact of LHTH protocol on cardio-respiratory variables, lactate response, iron profile indices, and lung function capacities to the performance enhancement of middle-long distance (MLD) runners. Methods: Seven MLD runners were trained LHTH for six weeks at 8000ft altitude. Cardio-respiratory variables ($\dot{V}O_{2max}$, VO_2/HR, VE_{max}, HR response), lactate response, iron profile indices (Hb, iron, UIBC, TIBC, transferrin, EPO, ferritin), and lung function parameters (FVC, FEV1, FEV1/FVC, PEF, and VC) were measured via standard protocols. Result: Hemoglobin (Hb, 7.8%), iron concentration (36.7%), and TIBC (8.2%) were found to be significantly increased after LHTH. On the other hand, $\dot{V}O_{2max}$ (6.4%) and PEF (10.7%) were found to be significantly ($p<0.05$) increased after camp. But HR_{rest} (1.8%), HR_{rec} (5min and 10min with 2.3% and 4.7% respectively), and lactate peak (7.9%) significantly decreased after LHTH condition. Discussion: All participating athletes improved performances after LHTH (overall group improved by 1.7%, individual increase up to 2.6%). Specific training load with hypoxic stress at high altitude induces peripheral chemoreceptor activation and stimulates sympathetic drive to initiate adaptive cascade leading to $\dot{V}O_{2max}$ improvement (improved group mean 6.4%, individually up

to 16.7%) which might be supported by enhanced erythropoiesis, iron metabolism, Hb concentrations, peak expiratory flow, glycolytic enzyme activity, enhanced oxidative capacity, improved resting and recovery HR response and peak lactate tolerance.

Key words: live high-train high, erythropoiesis, endurance performance, running performance, iron metabolism, lung functioning

Introduction

A high-altitude environment causes physiological stress in the body, which often happens at high altitudes (>3000 m) and moderate altitudes (2000 m to 3000 m). Hypobaric hypoxia is a condition caused by a drop in atmospheric oxygen pressure and a corresponding fall in barometric pressure as elevation rises (Vargas-Pinilla, 2014; Vissers, 2014). Along with hypoxia, many additional challenges, including strong sun radiation, low temperatures, low humidity, high winds, a limited dietary basis, hard terrain, etc., are significant elements that stress human physiological conditioning under high-altitude conditions (Vargas-Pinilla, 2014). It is necessary for people to adjust to the physiological stress of high-altitude exposure due to the reduced partial pressure of oxygen. Numerous variables influence these responses, including altitude-induced hypoxia, exposure length, exercise intensity, and individual conditions (Vargas-Pinilla, 2014). The body must undergo some adaptations and modifications at high elevations in order for the oxygen delivery system to make up for the hypoxia and keep the tissue oxygen levels sufficient for metabolism (Vargas-Pinilla, 2014; Vissers, 2014).

Hypoxic conditions are thought to activate glycolysis, up-regulate lactate and hydrogen ion transport, down-regulate the sodium-potassium pump, enhance capillary density, and increase pyruvate availability (Vissers, 2014; Wyatt, 2014). Where rapid fluid loss makes a person susceptible to dehydration, ventilation keeps becoming worse (Wyatt, 2014). Higher altitudes showed increased sympathetic activity, which eventually causes the HR_{max} to fall and the vagal tone to rise, down-regulating the beta receptors (Vissers, 2014). This comprehensive view aids in acclimatization and promotes cardiorespiratory adaptation to make up for the negative effects of higher elevations, which may be seen as an improvement upon returning to sea level. Although Saunders et al. (2009) have suggested that to get maximal benefit from LHTH protocol, some criteria should be followed: i) sufficient long stay (not < 2 weeks), ii) sufficient altitude (around 1800–2500 m), iii) iron profile should be proper and supply sufficient iron if needed, iv) design training meticulously and after initial physiological acclimatization.

Live high train high (LHTH) refers to athletes living and training at a natural high altitude for a period of time (usually 2–4 weeks) majorly aimed to improve sea-level performance. Coaches and athletes generally consensus about the LHTH improvements on physiological capacities and according to the meta-analysis of Bonetti and Hopkins (2009), LHTH leads to 1.6 ±2.7% improvement in performance for elite athletes. The LHTH has the potential benefit over Live High Train Low (LHTL) in terms of additional hypoxic training stress, which may accelerate erythropoiesis to increase the relative training intensity even more (Pugliese et al., 2014; Sharma et al., 2018). Factors that might explain these equivocal findings include the altitude at which athletes lived and trained, the relative intensity of training sessions, athlete iron status or supplementation protocol, and a reduction in training quality mediated by lower oxygen availability (Sharma et al., 2018).

There are studies that support both the ergogenic effect and those that disprove the hypothesis of the beneficial effect of LHTH on performance (Vargas-Pinilla, 2014; Saunders et al., 2009; Bonetti & Hopkins, 2009; Pugliese et al., 2014; Sharma et al., 2018). Although many physiological and biochemical factors parallelly worked in

sync with the hypoxic stress at higher altitudes to finally improve endurance performance. A limitation of many LHTH studies is that no clear training regimen was depicted, and many do not clarify the physiological percent changes to finally convert into performance changes in an individual manner. The present study sought to ascertain the impact of LHTH on the physiological and performance changes for a cohort of trained middle-long distance runners.

Methods

Subject selection

Seven (n = 7 including 3 girls and 4 boys; age = 16.4 ±1.51 years) middle-long-distance (MLD) runners of events 800m and 1500m with a minimum of four years of official training experience who are members of the Sports Authority of India (SAI) under the National Center of Excellence scheme participated willingly in the current study. The respondents were regarded as homogenous since they share the same socioeconomic status, dietary preferences, geographic location, meteorological circumstances, and similar exercise routines. Each individual involved in the study gave their informed consent, and the study procedure complies with the Declaration of Helsinki ethical principles.

Only athletes who were medically in good health, had no known genetic or cardio-respiratory disorders, and had undergone a clinical examination by a sports medicine professional prior to the start of the test were ultimately chosen for the current study. On a treadmill, each subject completed a graded exercise routine (T170 DE Sport Med., Cosmed srl, Italy). Assessments were carried out in two phases: 'before LHTH camps' and 'after LHTH camp' at sea level (at 123 m; Lucknow, Uttar Pradesh, India). Although none of the athletes had any previous experience of high-altitude camping.

Altitude training program

High altitude training camp was conducted at 8000ft (2400 m) above sea level at Shilaroo, Himachal Pradesh, India. The camp was continued for 6 weeks duration with an initial 7 days of the physiological adaptation phase. During the initial adaptation phase, daily monitoring of blood pressure, SpO_2, etc was followed to avoid excess physical stress. The training slowly started from the 8th day and the LHTH training load gradually increased in a weekly manner till the end. Total load was considered with the scoring of Rating of perceived exertion (RPE) following a modified Borg scale and weekly training volume (total kilometers covered in the week). The training was individualized for each athlete based on 'before camp' testing assessment, physical characteristics, performance target as per the current altitude training strategies, race pace, and some $\dot{V}O_{2max}$ intensity sessions were modified to include additional recoveries between intervals to maintain running speed, whereas threshold and low-intensity training were not modified (i.e., same interval/recovery length), but performed at a reduced speed and/or higher perceived effort compared to sea-level. A detailed morning session training plan was represented in Table 1. Where Monday was low-intensity running (6–10 km), Wednesday and Sunday were moderate-intensity running (10–20 km and 16–30 km respectively), Tuesday was interval running + hills ($\dot{V}O_{2max}$ intensity), Thursday was race pace, Friday was strength training and Saturday was threshold training. In the evening sessions, strength training was implemented on Monday, 30–40 min run at low intensity was implemented on Tuesday and Thursday, and a 6–8 km run at low intensity was implemented on Saturday. The overall volume of the evening sessions is moderately light in comparison to moderately higher loads in the morning sessions (Sharma et al., 2018).

Table 1. General structure of training week along with the initial week training plan (after 7 days of initial acclimatization) at high altitude

	MON	TUES	WED	THURS	FRI	SAT	SUN
The general structure of Altitude training (Mainly morning session)	6–10 km @ low intensity	Intervals + hills @ $\dot{V}O_{2max}$ intensity	10–20 km @ low to moderate intensity	Race pace	Strength training	Threshold	16–30 km @ low to moderate intensity
	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Initial week of training starts (after initial acclimatization)	Easy run	2 easy runs	2 runs or 1 medium length run	Threshold to $\dot{V}O_{2max}$	Strength training	Race pace	Long run

Anthropometric measurement

A digital Seca Alpha stadiometer was used to measure the standing height (cm), and a calibrated digital Seca Alpha weighing scale (model 770) was used to measure body weight (kg), also to the nearest 0.1 kg (Sarkar et al., 2020).

Iron profile and Erythropoietin measurement

Blood was drawn into a serum separator tube from the antecubital fossa vein, inverted 5–8 times, and left to coagulate for 30 minutes while the tube was upright. Serum separation was accomplished by centrifuging the blood for 15 minutes at 2200–2500 rpm. Iron, TIBC (Spinreact, Spain), and ferritin were measured from the separated serum (DrGdiagnostics, Germany). The cyanmethemoglobin method was used to measure hemoglobin, the enzyme immunoassay method for ferritin, and the Persjin method for TIBC. The following calculation was used to determine transferrin saturation: Iron/TIbc * 100. The HITACHI U-2000 Double beam UV/Vis spectrophotometer (Japan), ELx800 Absorbance Microplate Reader (Biotek, USA), and ERBA Smart wash-III, small automated ELISA washer (ERBA Diagnostics Mannheim GmbH, Germany) were the instruments utilized for these estimations (Srividhya et al., 2017). The Human EPO Quantikine™ IVD ELISA Kit (R&D Systems, Minneapolis, MN, USA) was used to measure the serum levels of EPO (Man et al., 2021).

Cardiorespiratory variables

The following cardio-respiratory variables were measured using a breath-by-breath metabolic gas analyzer (COSMED K5, Codmed Inc., Italy): oxygen pulse (VO_2/HR, ml/beats), pulmonary ventilation, or minute ventilation (VE, l/min), ventilatory equivalent for oxygen production (VE/VO_2), ventilatory equivalent for carbon dioxide excretion (VE/VCO_2), and $\dot{V}O_{2max}$, among others (Dhawan et al., 2014). Throughout the entire workout routine, a Polar heart rate monitor (Polar RS800CX, Polar Electro OY, Kempele, Finland) was utilized to track heart rate.

Prior to the commencement of the exercise test, each participant was briefed about the incremental exercise test protocol on the treadmill. The graded exercise test (GXT) was done by using the COSMED K5 (metabolic analyzer) on the treadmill by following the standard procedure of GXT to exhaustion, starting with 2min 6km/hr of warm-up on the treadmill followed by 2km/hr increment in every 2min with 2° inclination increase till exhaustion to reach the $\dot{V}O_{2max}$ limit (Marini et al., 2022). A built-in computer system connected to the COSMED K5 was used to record breath-by-breath data throughout the gradual exercise test. The 30-second sample period's average of the breath-by-breath cardio-respiratory data was then recorded (Sarkar et al., 2019).

Utilizing the COSMED K5, a direct method of metabolic gas analysis with the following standards, the maximum oxygen consumption ($\dot{V}O_{2max}$) was estimated. The following criteria must be met: i) VO_2 plateau (leveling off)

(2 $ml.kg^{-1}.min^{-1}$), (ii) respiratory exchange ratio (RER) 1.0, (iii) HR_{max}> 90% of age-predicted HR_{max} ±5% (Sarkar et al., 2019; Debray & Dey, 2007).

Following the ventilatory equivalent approach, AT was calculated (visual inspection). It occurs at a specific point when the VE/VO_2 increases but not simultaneously with the VE/VCO_2 (Sarkar et al., 2019; Nogueira & Pompeu, 2010). Two seasoned investigators visually assessed each person's AT determination process. The entire experiment was conducted in a space that ranged in temperature from 23°C to 25°C and relative humidity from 50 to 60%.

Spirometry measurement

Pneumotach Pony FX (COSMED pulmonary function equipment, Italy) was used to measure lung function. The test was administered to subjects in standing posture by using an inhaling mouthpiece and a nasal clip in accordance with the COSMED pulmonary testing protocol. FVC, FEV1, PEF, and VC were all directly measured. The conventional formula [(FEV1/FVC)x100] was also used to determine the forced expiratory ratio (percent). Before being extrapolated to a value for 1min stated in liters/minute, MVV was conducted over a 15s time period. A minimum of three tests were conducted, or until the two highest values were noted. Theophylline or ß-agonist inhalers were also forbidden before the test, as were exercise, alcohol, caffeine, smoking, and caffeine-containing beverages. A similar test was run twice: once before camp and once after camp, both times under the same climatic conditions: comfortable temperature (between 18 and 22 degrees Celsius), 760 millimeters of mercury, and 30 to 60 percent relative atmospheric humidity (Durmic et al., 2017).

Statistical analysis

The Statistical Program for the Social Sciences (SPSS) version 16.0 for Windows was used to conduct the statistical analysis (SPSS Inc., Chicago, Il, USA). The means and standard deviation of all values were used to express them (SD). The Levene's test and Shapiro-Wilk test were done to confirm the assumption of homogeneity and normality respectively. Effect size calculation was done via Cohen's d which was measured at 0.864, which falls under large (as Cohen's conventions 1988, >0.8 large). Using a paired sample t-test with two-tailed significance and a 95% confidence interval, differences between the means of the pre- and post-training groups for all variables were ascertained.

Results

Figure 1 depicted the mean comparative analysis of iron profile variables between the pre-and post-camp conditions of MLD players with individual player differences (shown as line graphs) from pre- to post-condition. Significant improvement was observed against some of the iron profile variables i.e., hemoglobin (7.8%) ($p = 0.031$, $t = –2.805$), serum iron (36.7%) ($p = 0.002$, $t = –5.168$), and TIBC (8.2%) ($p = 0.022$, $t = –3.072$) after camp conditions in comparison to pre-camp data. Whereas transferrin saturation (11.3%), and EPO (16.4%) were found to be increased and UIBC (1.3%), and ferritin (7.9%) were found to be decreased after camp but in a statistically insignificant manner.

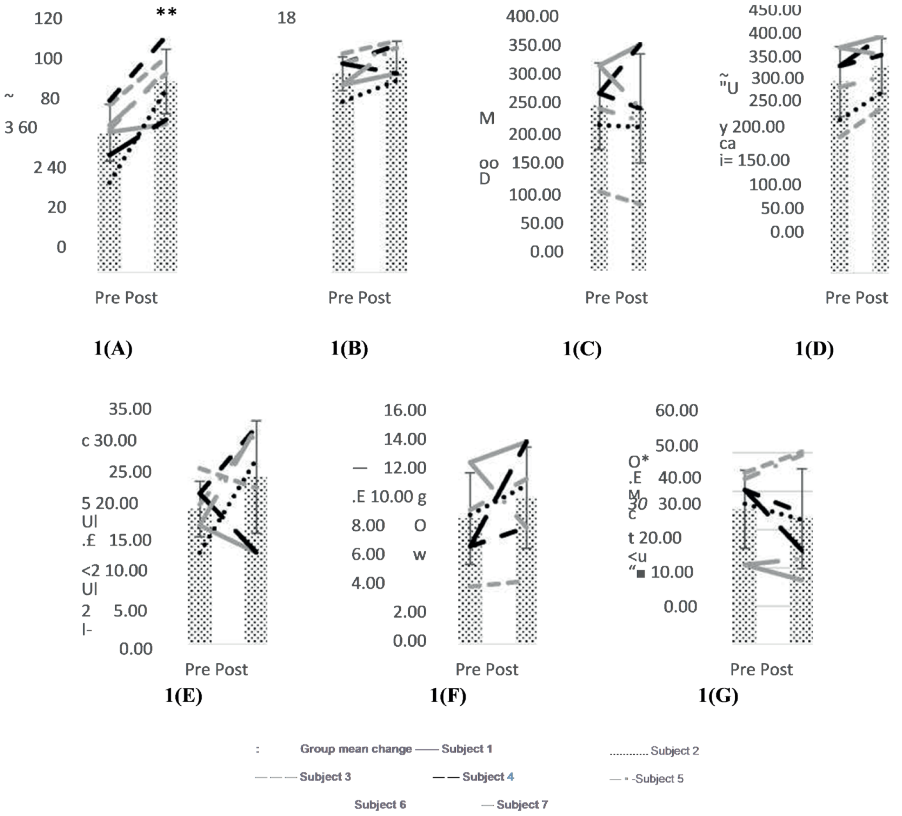


Figure 1. Comparative analysis of iron variables [1(A) iron, 1(B) hemoglobin, 1(C) UIBC, 1(D) TIBC, 1(E) transferrin saturation, 1(F) EPO, 1(G) ferritin] between the pre- and post-camp condition of MLD players with individual differences from pre to post condition.

[* = p < 0.05, ** = p < 0.01, UIBC= unsaturated iron-binding capacity, TIBC = total iron-binding capacity, EPO = erythropoietin]

Comparative profiling of cardio-respiratory variables between pre- and post-camp phases was represented in Table 2. Significant improvement was observed against some of the important physiological variables i.e., $\dot{V}O_{2max}$ (6.4%) (p = 0.042, t = –2.572) after camp conditions in comparison to pre-camp data. Whereas other cardiorespiratory variables i.e., HR at anaerobic threshold (1.0%), VO_2/HR (7.6%) were found to be increased and VE/VO_2(4.8%), VE_{max} (6.5%) was found to be decreased after camp but statistically insignificant manner.

Table 2. Comparative profiling of cardio-respiratory variables between the pre-and post-camp condition of athletes

Parameters	Pre-camp (n = 7)	Post-camp (n = 7)	t value	Sig.	% change
$\dot{V}O_{2max}$ (ml/kg/min)	64.50 ±4.31	68.66 ±5.26	–2.572	0.042*	6.4
HR at AT (bpm)	179.29 ±5.59	181.14 ±4.67	–0.734	0.491 NS	1.0
VO_2/HR (ml/beat)	19.40 ±4.40	20.87 ±5.34	–2.345	0.057 NS	7.6
VE/VO_2	31.16 ±4.12	29.67 ±2.27	1.109	0.310 NS	–4.8
VE_{max} (L/min)	114.41 ±15.83	106.94 ±27.66	1.306	0.239 NS	–6.5

*Values were expressed as mean ±SD, * = p < 0.05, NS= not significant, Sig. = level of significance, $\dot{V}O_2$max = maximal oxygen consumption, HR at AT = heart rate at anaerobic threshold point, VEmax = maximal ventilatory equivalent.*

Figure 2 represented the HR and lactate response (resting, peak, recovery 5 min, recovery 10 min) for both pre- and post-training conditions. Where, HR_{rest}, HR_{rec} (both 5 min and 10 min) were found to be significantly ($p < 0.05$, $p < 0.001$ respectively) decreased (1.8%, 2.3%, 4.7% respectively) in the post-training phase in comparison to pre-camp data. Whereas, only lactate peak was found to be significantly ($p < 0.001$) decreased (7.9%) in post-camp conditions.

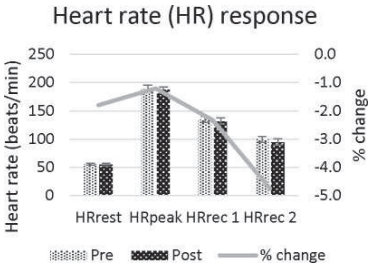


Figure 2(A)

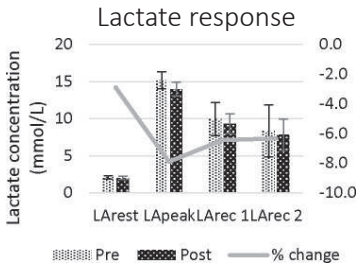


Figure 2(B)

Figure 2. Representing the (A) heart rate response and (B) lactate response. [HRrest = heart rate resting, $HR_{ma}x$ = heart rate maximum, $HR_{rec}1$ = heart rate recovery (5 min), $HR_{rec}2$ = heart rate recovery (10 min), LA_{rest} = lactate resting, LA_{peak} = lactatepeak, $LA_{rec}1$ = lactate recovery (5 min), $LA_{rec}2$ = lactate recovery (10 min)].

Table 3 depicts the comparative profiling of lung function variables between the pre-and post-camp phases of athletics players. Significant improvement ($p < 0.05$) was observed against PEF (10.7%) with $p = 0.013$ and $t = –3.496$ in the post-camp condition. Whereas all other lung function variables were found to depict statistically insignificant increase values in the post-camp phase in comparison to pre-camp data.

Table 3. Comparative profiling of lung function variables between the pre-and post-camp condition of athletics players

Parameters	Pre-camp (n = 7)	Post-camp (n = 7)	T value	Sig.	% change
FVC (L)	3.96 ±0.86	4.22 ±0.79	–0.684	0.519 NS	6.6
FEV1 (L/s)	3.48 ±0.69	3.63 ±0.73	–0.540	0.609 NS	4.4
FEV1/FVC (%)	85.57 ±4.93	87.86 ±4.91	–0.745	0.484 NS	2.7
PEF (L/s)	6.41 ±1.50	7.09 ±1.04	–3.496	0.013*	10.7
MVV (L/min)	134.00 ±23.79	138.63 ±19.93	–0.473	0.653 NS	3.5
VC (L)	4.55 ±1.17	4.70 ±1.01	–0.317	0.762 NS	3.4

Values were expressed as mean±SD, * = p < 0.05, NS = not significant, Sig. = level of significance, FVC = forced vital capacity, FEV1 = forced expiratory volume in 1sec, PEF = peak expiratory flow, MVV = maximum voluntary ventilation, VC = vital capacity.

Figure 3 depicted the percentage change in selected variables (i.e., $\dot{V}O_{2max}$, haemoglobin, iron content, and PEF) which were found significantly altered following LHTH training. Where, the group means change depicted 6.4%, 7.8%, 36.7%, and 10.7% changes by $\dot{V}O_{2max}$, haemoglobin, iron content, and PEF respectively.

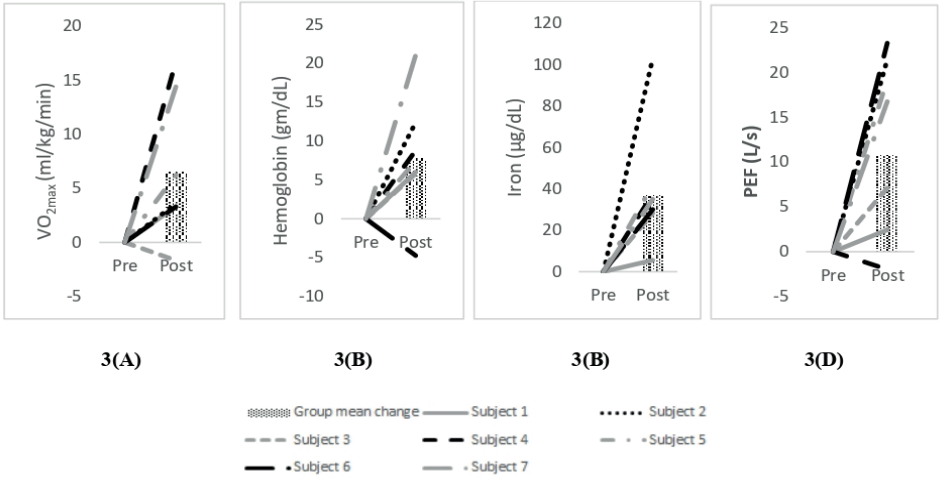


Figure 3. Represents the percentage change in some selected variables [(A) $\dot{V}O_{2max}$ (B) haemoglobin, (C) iron concentration, and (D) PEF values] following the LHTH training camp. Individual colored lines indicated individualizal plyers with histogram showing the group mean response. *[$\dot{V}O_2max$ = maximal oxygen consumption, PEF = peak expiatory flow*]

Table 4 depicted the changes in performance timing at the individual level after the LHTH training camp where both pre- and post-performance timings were taken at sea level, where the performance change ranges from 0.3–2.6% at an individual level.

Table 4. Individual performance changes following LHTH at high altitude

Athlete	Gender	Event	Performance time PRE (mm: ss)	Performance time POST (mm: ss)	% change
Subject 1	F	1500 m	4:39.19	4:34.45	–1.7
Subject 2	F	1500 m	4:41.08	4:37.21	–1.7
Subject 3	M	800 m	1:54.38	1:54.06	–0.3
Subject 4	M	1500 m	4:23.06	4:16.31	–2.6
Subject 5	M	800 m	1:55.46	1:53.28	–1.9
Subject 6	F	1500 m	4:39.60	4:33.39	–2.2
Subject 7	M	800 m	1:51.52	1:49.79	–1.6

Discussion

The objective of the current study was to assess the alteration in cardiorespiratory variables, iron profile characteristics, after LHTH camping, and its relation with time trials of performance for trained MLD athletes. A significant improvement in VO_2max, HR response (resting, recovery), lactate response (peak), and PEF value was observed after 6 weeks of the LHTH camp in the current study, which was conducted at an altitude of 8000 feet (2400 m) above sea level. These improvements were also significantly correlated with improvements in haemoglobin mass and iron concentration.

The present study result was consistent with those of earlier studies where the result showed a significant increase in plasma EPO concentration (16.8%), hemoglobin (7.8%), transferrin receptor concentration (10.1%), plasma iron concentration (43.1%), and a significant decrease in serum ferritin concentration (10.7%) (Man et al., 2021; Chen et al., 2014; Stray-Gundersen et al., 2001; Muraoka & Gando, 2012; Płoszczyca et al., 2018). The hypoxic state at high altitude, which stimulates erythropoiesis and results in an apparent increase in oxygen supply to peripheral tissue, may be the cause of the current observation of better iron profile variables (Stray-Gundersen et al., 2001; Muraoka & Gando, 2012; Płoszczyca et al., 2018). A minimum exposure duration of 18 to 22 hours over the course of three to four weeks at an altitude of >2100 m to 2500 m is sufficient to stimulate erythropoiesis by lowering PaO2 and raising EPO levels (Ge et al., 2002; Wilber et al., 2007). Improvements in hematological variables, particularly those related to iron profile, hemoglobin concentration, and controlling erythropoiesis by stimulating erythropoietin (EPO), will all help to improve endurance capacity, running economy, and overall running timings in middle-long runners (Man et al., 2021; Płoszczyca et al., 2018).

Vargas-Pinilla (2014) found that after 3–4 weeks of residing and training at an altitude > 2000 m, overall Hbmass and/or RBC mass significantly increased by 6–9%. Total hemoglobin and RBC mass are increased as a result of increased erythropoiesis and reticulocytes brought on by hypoxia, which in turn results in decreased plasma volume as a result of water loss, associated with hyperventilation and fluid shifting to interstitial and intracellular areas. Even after returning to sea level, improved hemoglobin and red blood cell mass are closely correlated with excellent endurance performance (Vargas-Pinilla, 2014; Muraoka & Gando, 2012; Heinicke et al., 2005). Endurance capacity is increased by activating EPO, transferrin for iron metabolism and RBC synthesis, and the glycolytic enzymes (phosphofructokinase, hexokinase, and lactate dehydrogenase) with enhanced glucose uptake and pH regulation. Another crucial element is the hypoxia-induced factor (HIF-1) (Man et al., 2021; Semenza, 2004; Vogt et al., 2001).

According to the current study, high-altitude training results in a substantial ($p < 0.05$) improvement in $\dot{V}O_{2max}$ (6.4%) in the post-LHTH camp condition compared to the pre-camp result. The findings of the current study concur

with those of Sinex and Chapman (2015) and Vargas-Pinilla (2014). According to the current research, high-altitude training will improve long-term adaptation and the ability of the cardio-respiratory system to function more effectively in aerobic conditions even when the workload is increased (Vargas-Pinilla, 2014). According to Ploszczyca et al. (2018), Heinicke et al. (2005), Vargas-Pinilla (2014), Muraoka and Gando (2012), and Stray-Gundersen et al. (2001), high-altitude induced hypoxia stimulates erythropoiesis and specifically improves the iron profile (EPO, Hb mass, etc.), which further stimulates and improves the anaerobic threshold, running economy, and ultimately the endurance capacity. Runners reported a considerable increase in muscle buffering capacity following two weeks of altitude training (between 2000 m and 2700 m), along with enhanced muscle myoglobin and oxidative capacity, which may also be the cause of the increase in $\dot{V}O_{2max}$. In order to boost endurance capacity, hypoxia-induced factor (HIF-1) persuaded adaptive regulation in skeletal muscle to activate EPO, iron metabolism, RBC synthesis, a glycolytic enzyme with improved glucose absorption, and pH regulation (Semenza, 2004; Vogt et al., 2001).

The present study depicted significant improvement in cardio-respiratory fitness as evidenced by i) an increase in maximal oxygen consumption ($\dot{V}O_{2max}$), ii) an increase in HR at anaerobic threshold, and iii) an increase in HR_{max} in post-camp condition after comparison with the pre-camp data. Heart rate response variables i.e., HR_{rest} ($p < 0.05$), recovery HR 5 min and 10 min (both $p<0.001$) were found to be significantly decreased with 1.8%, 2.3%, and 4.7% respectively in post-LHTH camp conditions which reflect the significant improvement although the HR_{peak} was not significantly improved. Cardiorespiratory factors from the current study are consistent with findings from earlier research by Sinex and Chapman (2015) and Vargas-Pinilla (2014). An increase in heart rate (HR) at the anaerobic threshold (AT) point, when comparing pre- and post-camp conditions, demonstrates a clear improvement in the anaerobic zone with stronger threshold response under increasing cardiac load (Vargas-Pinilla, 2014; Stray-Gundersen et al., 2001). A significant decrease in recovery HR and an insignificant decrease in resting HR was reported by Bhattari et al. (2018) and suggested that recovery completed within 5 min from step test cessation due to the parasympathetic reactivation as an effect of high-altitude training (Bhattari et al., 2018).

Along with the cardiorespiratory improvement the lactate rest, peak, recovery (5 min), and recovery (10 min) were found to be lower in the post-LHTH camp group with 2.8%, 7.9%, 6.5%, and 6.3% respectively in comparison to pre-camp data. The current finding is consistent with Vargas-Pinilla (2014), who observed that with increased endurance capacity, the total lactate response, including the peak and recovery, should decrease, indicating enhanced cardiorespiratory function. For a given workload, acute exposure to altitude causes an exacerbated lactate response characterized by increased lactate buildup in muscle and blood as well as lactate release from contracting muscle (Mazzeo, 2008). The levels of peak and submaximal blood lactate concentration do, however, decline relative to sea level (SL) with concurrent absolute exercise intensity as a result of acclimation. The drop in lactate happens despite the fact that VO_2 does not vary, and this phenomenon is known as the lactate paradox (Vargas-Pinilla, 2014; Mazzeo, 2008).

In the current study, under the lung function variables, only the PEF value showed a significant ($p < 0.05$) increase in the post-camp condition (10.7%). While all other lung function measures, including FVC, FEV1, FEV1/FVC, MVV, and VC, were shown to have improved after LHTH camp conditions by 6.6%, 4.4%, 2.7%, 3.5%, and 3.4%, respectively, the improvement was not statistically significant. The current study's findings are consistent with those of earlier research (Faramoushi et al., 2012; Valizadeh et al., 2012; Mason et al., 2000). According to the current research, decreased airway resistance and decreased air density at high altitudes lead to increased PEF (Faramoushi et al., 2012). The strengthening of ventilatory muscles during high-altitude training, where the air

density and resistance, as well as atmospheric pressure at greater altitudes, were lowered, maybe the cause of the overall increase in lung function capacity (Faramoushi et al., 2012). High altitude induces a rise in the hormone adrenalin, which reduces the reversibility of the lungs and dilates blood vessels. As a result, airway resistance decreases, which may be another factor contributing to improved ventilation (Valizadeh et al., 2012).

The present study resulted in performance time trial improvement ranging from 0.3–2.6% (varies individually) following 6 weeks of LHTH camp at 2400m altitude which was supported by the significant $\dot{V}O_{2max}$ at an individual level. Although as per the literature, the LHTH-induced improvement in maximal aerobic power may be further supported by an increase in serum erythropoietin (EPO) levels and a series of accompanying physiological responses, e.g., increases in red cell volume (RCV) and hemoglobin (Hb) concentration, an increased erythrocyte concentration of 2,3-diphosphoglycerate (2,3-DPG) causing a rightward shift of the oxyhemoglobin dissociation curve, development of capillary density; an increase in mitochondrial capacity, oxidative enzyme activity, glycogen sparing, FFA mobilization, lactate threshold, muscle buffering capacity, and muscle myoglobin content have taken place after LHTH protocol as a result of the performance time decreased significantly with a sufficient stay at moderate-high altitude for 3–4 weeks' time (Muraoka & Gando, 2012). Some of these were measured in the present study and Hb concentration, iron content, HR response (resting, recovery), lactate response (peak), and PEF value were found to be improved significantly and support the fact of performance time trials improvement at the individual level.

One of the main drawbacks of the study is that there were only seven middle-long distance runners who took part. As a result, the study is regarded as a pilot study in a particular population cohort.

Conclusions

In order to improve running economy and maximum aerobic capacity, the LHTH protocol is especially helpful for endurance athletes (MLD runners). Significant improvements in cardio-respiratory variables, i.e., endurance capacity, running economy with a faster heart rate, and lactate recovery, were induced by high-altitude training. Decreased PaO_2 and a hypoxic stimulation at higher altitudes may trigger a number of transcription factors that control iron profile improvement added with improved lactate response. All participating athletes achieved lifetime personal best performances after the LHTH (overall group time trials improvement of 1.7%, individual improvement up to 2.6%). Individual improvements in maximal aerobic capacity (improved group mean of 6.4%, up to 16.7%) may be supported by improved erythropoiesis, iron metabolism, Hb concentrations, peak expiratory flow, glycolytic enzyme activity, improved oxidative capacity, and improved resting metabolic rate in response to a specific periodized training load with hypoxic stress at 2400 m altitude. The present study also suggests that periodization should be individualized and summative load volume response (addition of hypoxic physiological load and weekly training load) should be maintained during training. Also, the iron profile of those players before camp condition should be normal/optimal to get the LHTH benefits and they should get sufficient 6–7 days of initial physiological adaptation before starting training at high altitude. Altitude sickness and overtraining are two common concerns at LHTH training that should be closely monitored.

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EVIDENCE FOR THE PSYCHOMETRIC PROPERTIES OF THE COMPONENT TEST ITEMS IN THE EUROFIT TEST BATTERY ADMINISTERED TO ELITE SCHOOLBOY RUGBY UNION PLAYERS: A TEST-RETEST RELIABILITY STUDY

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Abstract Rugby is a popular sport and requires participants to have commensurate physical attributes for effective participation. One physical fitness test battery which enjoys extensive use contextually is the European Test of Physical Fitness (Eurofit). However, the psychometric properties of the test battery have not been explored and documented in the local context. Therefore, this study was conducted to examine the test-retest reliability of the Eurofit test battery items among elite schoolboy rugby players in Harare, Zimbabwe. Thirty-two (32) players with the mean age of 17.2 (SD = 1.03) years completed all the tests during the in-season period. Anthropometric and Eurofit test measurements were obtained twice with seven days separating the assessments. The Intraclass Correlation Coefficient (ICC) estimated the reliability of the test items. The global ICCs for the Eurofit test items ranged from 0.59 to 0.98. The Sit-and-Reach test yielded the highest temporal reliability (ICC = 0.98). The Plate

Tapping test, Flamingo Balance test and 10 × 5m Shuttle Run test showed ICCs < 0.7. Cognisant of the study limitations, some component test items of Eurofit test battery can be recommended for reliably evaluating aspects of physical fitness in junior rugby players in Zimbabwe whilst others still need consideration and test modification.

Key words: test-retest reliability, rugby, adolescents, Junior, Eurofit test battery

Introduction

Rugby union (hereafter referred to as "rugby") is a popular sport played at different competitive levels in more than 100 countries worldwide (Abernethy & MacAuley, 2003; Brown et al., 2012; Spamer & De la Port, 2006; Duthie et al., 2006). Approximately, 171 000 adults and children play rugby at school and club level in Australia (Gabbett & Domrow, 2005). Reportedly, about 400 000-500 000 South African children, adolescents and adults play rugby (Brown et al., 2012). In addition, rugby is increasingly gaining popularity in many low-income countries previously not known for rugby on the international arena such as Zimbabwe (Nemadire, 2013).

Although little is known about Zimbabwean rugby worldwide, it is, arguably, one sporting discipline the country has a comparative advantage over most countries on the African continent. Much of the strength of Zimbabwean rugby at national level is grounded on a strong school-based male junior rugby system (Chiwaridzo et al., 2015). Central to this discussion, has been the establishment of the so called Super Eight Schools Rugby League (SESRL) which features the "elite" eight rugby-playing high schools in the country (Chiwaridzo et al., 2015). The schools in the SESRL variably expose talent-identified Under 13 (U13) to Under 19 (U19) rugby players to an optimal environment for learning and practising rugby under the auspices of reputable and well-acclaimed rugby coaches. This is done through the provision and availing of superior coaching services, excellent training facilities, adequate training resources, early specialisation services, selective scholarships, medical and physiotherapeutic services, and exposure to elite regional or international schoolboy rugby events. Annually, this league produces U19 players capable of joining professional and semi-professional senior clubs enhancing their chances for representing the country in the future. Hence, the SESRL forms the bedrock of Zimbabwe senior rugby as it continuously produces young players capable of embarking into professional rugby.

Since rugby is a physical sport, injuries are inevitable (Bleakley et al., 2011; Freitag et al., 2015; Kaux et al., 2015; Gabbett, 2003). Recent systematic reviews on rugby injuries for adolescents under the age of 21 years reported alarmingly high incidence rates between 27.5 and 129.8 per 1 000 match hours (Bleakley et al., 2011; Freitag et al., 2015). Unfortunately, there is limited information on the epidemiology of adolescent injuries in Zimbabwe. The little that is known about rugby-related injuries includes documented findings from a cross-sectional study profiling injuries sustained by 275 junior players in one competitive season of the SESRL (Chiwaridzo et al., 2015). The study reported injury rates, pattern and anatomical distribution of rugby injuries which were consistent with numerous regional and international studies on schoolboy players. These findings suggest that Zimbabwean schoolboy rugby players are vulnerable to injuries common in rugby as the rest of young rugby players from other countries.

The reported impact of rugby injuries, particularly among adolescents, should stimulate interest among coaches, sports scientists and physiotherapists. Against the background of recent findings on injuries and the level of competiveness exhibited in the SESRL (Chiwaridzo et al., 2015), research directed towards understanding the

risk factors for rugby-related injuries in junior rugby players in Zimbabwe is paramount. Although there are many factors, impaired physical fitness levels have been linked to acute and recurrent rugby-related injuries (Gabbett & Domrow, 2005; Gabbett, 2000). In Zimbabwe, there is no study that has provided scientific evidence on the physical fitness levels of junior rugby players especially those participating in the competitive SESRL. Lack of such evidence is a significant shortcoming undermining credible preventative efforts in minimising injuries. However, as physical fitness is a multidimensional construct, it is essential, firstly, to establish the psychometric properties of physical test batteries commonly used in the Zimbabwean context to assess physical fitness of adolescent rugby players. Afterwards, it becomes logical to determine the normative values for physical fitness items for the Zimbabwe junior rugby population. Studies evaluating the relationship between physical fitness and injury risk could then be conducted based on test batteries which are psychometrically sound and contextually relevant.

Local rugby coaches and physical fitness trainers currently enjoy extensive use of the component test items of the European Test of Physical Fitness (Eurofit), evaluating the level of physical fitness among rugby players. This is particularly so for tests such as the Sit-and-Reach test and the 10 × 5 m Shuttle Run. Nonetheless, no information is available on the reliability of the Eurofit test battery in the Zimbabwean context. Although the reliability of the Eurofit test battery has been explored in various populations mainly from high income countries such as in Europe, less research has been conducted in this area particularly targeting young “elite” athletes living outside Europe. It is possible that differences in lifestyle, socio-economic status, playing standards, playing styles, training-related factors, and player recruitment strategies among other factors may affect direct extrapolation of results from other studies conducted in other countries. Evidence on the psychometric properties from other countries is thus unlikely to be transferrable and generalisable to inform the reliability of the Eurofit test items in a totally different context with a different organisation of the sporting activities. Therefore, an attempt to address this problem using Zimbabwean schoolboy rugby players seems scientifically interesting and offers great prospects, for example, for the development of standards or norms for this population of athletes in the future. This is particularly important given that competitive schoolboy rugby is still an emerging phenomenon gaining unparalleled attention and acceptance in Zimbabwe.

An understanding of the relative reliability of the Eurofit test items in an African context using a sample of elite adolescent rugby players is important for rugby coaches, rugby sport directors, sports scientists, medical rehabilitation professionals and the players. Urgently, such information would rationalise the use of constituent Eurofit test items in the cross-sectional and longitudinal monitoring of the level of physical fitness of adolescent rugby players and would further provide some justification for inclusion of some component Eurofit test items in test batteries used during talent identification (TID) programmes. Moreover, local rugby coaches, sports scientists and physiotherapists may reliably use the Eurofit test battery in injury surveillance and in evaluating the effectiveness of developed and implemented rehabilitation programmes. Against this background, this study was conducted with the broad aim of establishing test-retest reliability of the Eurofit test battery among junior male rugby players from schools participating in the elite SESRL based in Harare, Zimbabwe. Specifically, the study sought to determine the candidate items in the Eurofit test battery that would achieve a high Intraclass Correlation Coefficient (ICC) of greater than 0.7 between the test-retest assessments separated by seven days (7) when assessed during the in-season period of the elite schoolboy rugby league, the SESRL.

Methods

Study design, research setting and participants

Experimentally, a test-retest study design was conducted to establish reliability of the component test items of the Eurofit testing battery using a sample of junior male rugby players. A pragmatic approach for assessing the absolute and relative reliability of test items during the "in-season" period as previously used by Enright et al. (2018) was adopted for this study. The study targeted private and public schools playing rugby in the SESRL. This is the most competitive, exceptionally organised and well-sponsored junior rugby league in Zimbabwe (Chiwaridzo et al., 2021). All the SESRL schools have a local reputation for having a strong and long-standing culture of playing highly competitive rugby, hence the amalgamation and aggregation of these eight schools to form an "elite" junior league. In the selected schools, the study targeted schoolboy rugby players playing as U19s. Using tables derived from Walter et al. (1998) study, the estimated sample size was 18 based on the following parameters H0: p0 (minimally acceptable level of reliability) = 0.7, H1: p1 = 0.9 (maximum expected value of reliability), beta (β) = 0.2, alpha (α) = 0.05. However, due to multiple tests in the test battery and the study design involving two repeated measures, over-sampling was done. Firty-six (56) elite U19 players were available for participation.

Eligibility criteria

Only players willing to participate were included in the study. However, players had to have a signed informed consent form from their parents granting them permission to participate. Since data were collected when the SESRL was in its third (3rd) week of competition (*all the schools had played three competitive match games*), eligible schoolboy rugby players had to indicate having played at least two competitive matches, either for the first or second U19 team, to be included in the study. This was done to involve players in their peak physical condition. To further select appropriate players, an exclusion criteria adopted and modified from a study conducted by Green et al. (2011) was used. Players with reports of (un)diagnosed musculoskeletal injuries in the last eight weeks, verified by the players and the coaches, which could be aggravated by physical exertion were excluded. This means also that players not playing or training with the rest of the team because of covert or overt injuries or illnesses were also excluded. Additionally, players with any reports of neurovascular or cardiorespiratory symptoms such as numbness or tingling in the lower limbs or upper limbs, headaches, chest pains, episodic dyspnoea and fatigue were excluded. Furthermore, players had to be present in training on the day of testing for them to be included.

Instruments

Pre-measurement Demographic Questionnaire (PMQ): The PMQ was used to gather data on socio-demographic and rugby-related information of participants. Information elicited included age, place of residence, school, player position (forward vs. backline), specific player position (*for players that often changed positions, they had to state their regular position*), years playing school rugby and number of competitive games played in the season to the point of testing.

Physical Activity Readiness Questionnaire (PAR-Q): The PAR-Q was used as a pre-screening tool for the rugby players prior to partaking in Eurofit measurements to evaluate their general health and suitability to participate in the study. The PAR-Q has been used in similar studies involving rugby players as a screening tool for eligibility and its psychometric properties are well-established (Green et al., 2011).

Body weight scale: Body weight was measured using a SECA body weight scale. The weight was considered as an average of two best measurements that agreed within 0.1 kg. The participants were measured in light clothing (shorts and rugby jerseys) and shoes removed.

Stadiometer: Standing height was measured using a Stadiometer. The height was considered as an average of two best measurements that agreed within 0.1 cm. The participants were measured in light clothing (shorts and rugby jerseys) and shoes removed.

Eurofit testing battery

The Eurofit test battery was introduced in 1988 by the Committee for the Development of Sport of the Council of Europe for the evaluation of physical fitness in children and youth. Since introduction, the test battery has enjoyed wide application in research studies on different sample populations (Erikoglu et al., 2015; Vancompfort et al., 2015; Keane et al., 2010; Tsigilis et al., 2002; Vancompfort et al., 2012). In this study, we examined the reliability of the Sit-and-Reach test (flexibility), Bent Arm Hang test (muscular endurance or functional strength), Handgrip test (static arm strength), Standing Broad jump test (explosive leg power), Sit-Up test (trunk strength), Plate Tapping test (coordination or reaction speed), Flamingo Balance test (single leg balance test) and the 10×5m Shuttle Run (running speed and agility).

Outline of the school rugby activities

In Zimbabwe, schoolboy rugby is a winter sport played during the second term of the school calendar from May to September for 15 or 16 weeks. However, intense preparations begin during the pre-season period from February to April of every year. The pre-season period is characterised by player mobilisation, recruitment, health screening, pre-season training, early conditioning, friendly inter-scholastic rugby matches, international and regional tours, and participation in the annual rugby festival called the Dairiboard Zimbabwe Schools Rugby Festival (DZSRF). All these events are in preparation for the commencement of the SESRL league in May. In the second term of the school term, the SESRL begins with schools playing home and away games. This study was conducted during that in-season period.

U19 male rugby players had five (5) days of training sessions per week from Monday to Friday, emphasising various aspects of game technique, skills, tactics, physical training, speed training, aerobic conditioning, and simulated match games. Each training session lasted approximately three hours (14:00hrs–17:00hrs). The U19 schoolboy rugby players were allowed one day of (un)supervised training session per week emphasising resistance training in the gymnasium before commencement of regular field training. The gymnasium sessions were conducted every Wednesday between 12.00pm to 14.00pm at the selected schools. Inter-scholastic SESRL competitive matches were scheduled for every Saturday. Sundays were designated as recovery days, before resumption of light training next Monday. Training intensity heightens midweek (Tuesday, Wednesday, and Thursday) and lightens towards Saturday in preparation for the competitive match.

Data collection Procedure

Ethical approval and institutional permissions

Before data collection, the Joint Research Ethics Committee (JREC) of the University of Zimbabwe checked the aims, design, materials and procedures of the study and approved as it is ethically acceptable and follows the research code of the university. Additionally, ethical permission was also granted by the Medical Research Council of Zimbabwe (MRCZ) since the study involved adolescent participants found in the general public or private schools. Institutional approvals were granted by the Ministry of Primary and Secondary Education, Harare Provincial Education Directorate and the respective school principals. Written informed consent was obtained from parents/legal guardians of participating students. All students gave written assent as an expression of willingness to participate.

For ease of description, the procedure for data collection is discussed in three main stages: The Preparatory, Familiarisation, and Test-Retest stage.

Preparatory stage: During this stage, the research team visited participating schools to meet the school authorities and the coaches to explain the purpose, methodology of the study and to agree on dates for data collection. We also used this opportunity to address players explaining the rationale, procedure, risks and benefits of the study. Thereafter, students who verbally agreed to participate were given information letters and informed consent forms for parents. The students were given five days to return signed informed consent to the coaches. The researchers would remind the coaches using Short Messaging Services (SMSs) to collect returned documents. The researcher (TM) collected returned documents at the end of the week. Students with signed informed consent were then eligible to participate in the study.

Familiarisation stage: On agreed dates with the coaches, the research team visited the two participating schools to familiarise the eligible students to the candidate items of the Eurofit testing battery. This is in agreement with the recommendations made by Duthie et al., (2006) and Gabbett (2005). The familiarisation process entailed explaining the purpose of each test, the testing procedures involved and the outcomes to be recorded for each candidate item of the Eurofit test battery. Subsequently, the research assistants would demonstrate practically how the tests are conducted and allowed the players to practice. The familiarisation sessions were done until all the eligible players subjectively reported that they were satisfied and adequately knowledgeable on the procedure of each test in the Eurofit test battery.

Test-retest assessment: On agreed dates with the coaches, the research team visited the selected schools for test-retest measurements. This was conducted exactly two weeks after the familiarisation sessions. Eligible players completed pre-measurement demographic questionnaires and the PAR-Q. All the Eurofit measurements were conducted following standardised procedure. In both schools, data were collected after school hours (14.00–17.00hrs) in the rugby sports field during practice/training sessions. Owing to limited daily training time for the players and the extensive number of Eurofit tests to be performed by the research team, the coaches specified the days when the Eurofit measurements had to be conducted. Therefore, the tests had to be staggered for over three days as shown in Table 1. On the request from the coaches, the fitness testing took place 30–45 minutes before training on each testing day. The order of the tests was guided by the recommendations given by Turner et al. (2011). It involved performing simple and physically challenging tests together as opposed to conducting all

physically challenging tests in one testing session. The re-test assessments for each specific test were conducted exactly seven days after by the same investigator following the same procedures.

Table 1. Summary of the test protocol for the Eurofit

Day	Tests (Abbreviation)	Physical fitness component measured
Monday	Height (H)	Height (m)
	Weight (W)	Weight (kgs)
	Sit and reach test (SAR)	Flexibility (cm)
	Handgrip test (HGR)	Static arm strength (kg)
Wednesday	Flamingo balance test (FBT)	Balance (n)
	Plate Tapping test (PLT)	Coordination or reaction speed (s)
	10±5m shuttle run (SHR)	Running speed and agility (s)
Friday	Sit up test (SUP)	Abdominal strength/endurance (n)
	Bent arm hang (BAH)	Upper body muscular endurance
	Standing broad jump (SBJ)	Explosive leg power (m)

Description of the tests

Sit-and-Reach (SAR) test: This test was used to measure hamstring and lower-body flexibility. Participants would warm-up for three minutes with general flexibility stretches. In sitting position, participants would extend their legs and spread their feet into the SAR box. The test involved the participants placing their feet against the wall of the SAR box and extending their arms slowly, one on top of the other, pushing a ruler placed on the top of the SAR box and held the final position for at least two seconds (Mayorga et al., 2012). The test was performed twice and the better of the two measures was recorded.

Standing broad jump (SBJ) test: Explosive lower-limb strength was measured using the SBJ test. The participants stood with feet parallel and shoulder width apart on the marked starting line. Participants were instructed to swing their arms, flex their knees and jump as far as possible trying to land with both feet together (Houwen et al., 2006; Ruiz et al., 2006). The participants would repeat the test if they fell backward or touched the floor with another part of the body. The distance jumped was recorded from the marked line to the farthest point backward of the participant recorded using a tape measure. The participants were allowed to practice two demonstration trials before they could perform the actual test. The SBJ score represented the best score of the two trials performed.

Handgrip strength test (HGR): Handgrip strength was assessed using the HGR test. After explaining the rationale of the test and demonstrating the procedure, participants were instructed to hold the dynamometer to the side of their body, arm fully extended, and palm facing inward (Houwen et al., 2006). The dynamometer would be compressed with maximal effort for 2–3 seconds (Donncha et al., 1999). Dominant handgrip measures were read to the nearest 0.1 kg. The participants were allowed to practice two demonstration trials before they could perform the actual test.

Sit-up test (SUP): The SUP test used to assess abdominal endurance. The participants would be instructed to lie in supine position on a mat (Keane et al., 2010). In preparation for the test, the participants would be instructed to bend their legs to 90 degrees, put their feet flat on the mat and the research assistant would stabilise them at the ankles (Skowronski et al., 2009). The participants would then place their hands at the back of the head with

the fingers interlaced. A full sit-up was recorded when the participants touched their knees with the elbows and returned the shoulders to the ground. The SUP score was recorded as the maximum number of sit-ups achieved in 30 seconds.

10 ±5m shuttle run (SHR): Running speed was measured using a 5 × 10 m shuttle run. Each participant was required to sprint 10 times between two lines placed 5 m apart over a 1.3 m wide track. The sprint was followed by immediately turning and running back. The SHR test score was the time required to run 10 × 5 m measured in seconds (Fjørtoft et al., 2011; Duthie et al., 2006).

Flamingo balance test (FBT): Single leg standing balance was assessed using the flamingo balance test as the number of trials needed by individuals to achieve a total duration of 30 s in balance on their preferred foot on a flat firm surface. While balancing on the preferred foot (shoes removed), the free leg would be flexed at the knee and the foot of this leg held close to the buttocks (Tsigilis et al., 2008). The participants were allowed to place their arms on the researcher's shoulder for the initial balance. The test began the moment the participant released his supporting arm from the researcher's shoulder.

Plate tapping test (PLT): Plate tapping test was used to measure the speed of the arm (Monyeki et al., 2005). Two plastic discs measuring 20 cm in diameter were placed on a flat surface with their centers 60 cm apart (Telles et al., 2013). In between the two discs, a white rectangle paper was placed measuring 30 × 20 cm. The participants were instructed to place the non-preferred hand on the rectangle and move the preferred hand back and forth between the two discs over the rectangle. Two taps counted as one cycle and the participants were asked to complete 25 cycles as fast as possible. The item score was the time taken to complete 25 cycles.

Bent arm hang (BAH): This test evaluated the upper-limb endurance strength. The participant had to maintain a bent arm position while hanging from a bar with hands in a forward grip and at shoulder width position. The participant's chin had to be above the bar. The participant had to hold this position as long as possible without resting the chin on the bar. The test ended when the participant's eyes went the below the bar. The score was the total time taken recorded in seconds.

Statistical analysis

Statistical Package for Social Sciences (SPSS) was used for statistical analysis. Descriptive statistics described age, playing position and body mass index (BMI) for the sample participants. The independent t-test compared the mean ages and BMI of the participants by player position. One way analysis of variance (ANOVA) compared the mean age and BMI by specific position. The dependent t-test assessed the mean differences between test-retest results for the Eurofit items. The p-value for statistical significance was set at 0.05. Reliability was analysed using Intraclass correlation coefficient (ICC). The ICCs values expressed the absolute agreement between single measures on a two way mixed model (3, 1). Reliability coefficients were satisfactory for an ICC greater than 0.7 (Terwee et al., 2007; Turner et al., 2011). The standard error of measurement (SEM) was computed for each candidate item as the standard deviation (SD) multiplied by the square root of 1-ICC [SD x (square root of (1-ICC)] (de Vet et al., 2006).

Results

Sample characteristics

Of the 40 players given permission by their parents/legal guardians to participate, 38 volunteered to participate of which 32 completed all the Eurofit items in the test-retest study. The demographic and rugby-related information for the sample participants are shown in Table 2. The mean age of the participants was 17.2 (SD = 1.03) years. There was no significant difference in the mean ages between forward and backline players [t (30) = –1.26, p = 0.22]. There was no significant difference in the mean age by specific positions of the players [F (8, 23) = 0.86, P = 0.56]. There was a significant difference in the BMI by position [t (30) = 2.18, p = 0.04]. On average, backline players had a mean BMI of 22.7 kg/m^2 (SD = 1.76) compared to 25.1 kg/m^2 (SD = 3.70) for the forward players. There were no significant differences in the mean BMI by specific player position [F (8, 23) = 2.17, p = 0.07]. The mean years of experience playing schoolboy rugby was 4.81 (SD = 1.4) years. On average, participants played 2.2 (SD = 0.8) competitive games at the time of data collection.

Table 2. Sample demographic characteristics and rugby-related information (N = 32)

Variable	Response	n (%)
Age (years)	15	2 (6.3)
	16	6 (18.8)
	17	10 (31.3)
	18	12 (37.5)
	19	2 (6.3)
Playing positions	Forward	19 (59.4)
	Backline	13 (40.6)
Specific playing positions	Lock	7 (21.9)
	Centre	2 (6.3)
	Flank	6 (18.8)
	Fly-half	1 (3.1)
	Fullback	3 (9.4)
	Hooker	4 (12.5)
	Prop	2 (6.3)
	Scrum-half	4 (12.5)
	Winger	3 (9.4)
Body mass index (BMI)	Normal	25 (78.1)
	Overweight	5 (15.7)
	Obese	2 (6.3)

Test-retest reliability results

Table 3 shows descriptive statistics for the Eurofit items for the test-retest reliability study and the ICCs calculated at 95% confidence interval. The ICC values for the candidate items in the Eurofit test battery ranged from 0.51 to 0.98. The Sit-and-Reach test yielded the highest test-retest reliability values (ICC = 0.98). The only tests with ICCs values of less than 0.7 were the Flamingo Balance test, Plate Tapping test and the 10 ±5 m Shuttle Run test.

Table 3. Test-retest results (N = 32)

	Test	Retest					
Test	Mean (SD)	Mean (SD)	*t*-test	*p*-value	ICC	95% CI	SEM
FBT (n)	0.53 (0.91)	0.36 (0.71)	1.09	0.28	0.51	0.21–0.73	1.00
PLT(sec)	12.4 (1.42)	11.9 (1.31)	0.36	0.72	0.59	0.31–0.78	1.44
BAH (sec)	19.1 (11.1)	21.1 (11.0)	–2.43	0.02	0.90	0.78–0.95	6.83
SBJ (m)	2.07 (0.23)	2.04 (0.19)	1.18	0.25	0.82	0.67–0.91	0.17
HGR (kgs)	49.9 (7.09)	50.5 (7.74)	–1.08	0.29	0.89	0.79–0.95	4.79
SAR (cm)	14.3 (8.06)	13.7 (8.58)	1.40	0.17	0.98	0.95–0.99	2.55
SUP (n)	24.0 (4.45)	25.0 (4.89)	–1.90	0.07	0.73	0.51–0.88	4.56
SHR(sec)	16.3 (1.33)	16.1 (1.64)	0.86	0.40	0.60	0.32–0.78	1.69

SD = standard deviation, sec = seconds, kgs = kilograms, m = meters, n = number, cm = centimetres, ICC = Intraclass correlation coefficient, CI-confidence interval, SEM = standard error of measurement, FBT = flamingo balance test, HGR = handgrip test, PLT = plate tapping test, BAH = bent arm hang, SAR = sit and reach test, SBJ = standing broad jump test, SUP = sit up test, SHR = shuttle run test

Discussion

This study was conducted to provide baseline information on the test-retest reliability of the Eurofit test battery administered to elite Zimbabwean junior rugby players in high schools. Our findings showed that the majority of the Eurofit candidate items yielded high test-retest reliability with ICCs greater than 0.7. Exceptions were for the Plate Tapping (ICC = 0.59), Flamingo Balance (ICC = 0.51) and the 10 × 5 m Shuttle Run tests (ICC = 0.60). The studies specifically evaluating test-retest reliability of the Eurofit test battery among junior rugby players are limited in the literature. This renders comparisons of our present findings with other findings obtained from studies involving similar participants difficult. Nonetheless, there are innumerable studies conducted in different settings utilising different participants that have evaluated the test-retest reliability of the Eurofit test battery (Erikoglu et al., 2015; Vancompfort et al., 2015; Keane et al., 2010; Tsigilis et al., 2002). For example, Tsigilis et al. (2002) examined one-week test-retest reliability of the Eurofit test battery among 98 male and female physical education university undergraduate students (aged 19.45 ±2.7 years) in Greece. In that study, the Eurofit test battery yielded reproducible data for the majority of the tests with global ICCs values ranging from 0.57 to 0.94. Similarly, Houwen et al. (2006) reported ICC values between 0.63 and 0.91 using 21 Dutch school-children, aged 6–12 years, with visual impairments. In that study, the test-retest assessment sessions were separated by four (4) weeks. In Northern Ireland, Donncha et al. (1999) reported ICC values of 0.85 to 0.99 for the physical test items of the Eurofit for 22 healthy males aged 15.6 ±0.6 years in Ireland. Variability in the global reliability values could be explained largely by population and methodological (test-retest time interval) differences. In spite of these differences, our present study findings provide support for the reliability of Eurofit test battery in assessing physical fitness in the studied sample. These findings are important to coaches, sports directors and fitness coaches involved in local high school rugby since some of the candidate items of the Eurofit test battery are commonly used in training already.

The SAR test for hamstring and lower-back muscle flexibility yielded the highest temporal reliability with an ICC of 0.98. This reflected an almost perfect agreement in the test scores between the test and retest assessment. In concordance, Tsigilis et al. (2002) reported an ICC of 0.94 in physical education students who were slightly older than our sample participants. Similarly, Donncha et al. (1999) reported ICC values of 0.97 for participants with mild retardation and 0.91 for those without. Our present findings indicate that the SAR test can be proposed for the reliable evaluation of hamstring and lower-back muscle flexibility in junior rugby players in Zimbabwe.

Other candidate items of the Eurofit that achieved satisfactory reliability values included the BAH test for muscular strength and endurance (ICC = 0.90) and the HGR test for isometric muscle strength of the hand and forearm (ICC = 0.89). All these findings highlight the suitability and reliability of these tests to be used in examining static muscular strength and endurance of the upper limbs. There is incontrovertible evidence in the literature showing that the reliability of these tests is population specific (Monyeki et al., 2005). Fjørtoft et al. (2011) reported low reproducibility values for the BAH test in young children aged between the ages of five and seven years. In contrast, Tsigilis et al (2002) reported a high ICC of 0.89 for the BAH test in physical education students. The test also showed a relatively high coefficient of variation (CV) of 18.6% indicating huge variability in the scores in the test-retest reliability study. Of all the Eurofit tests investigated in the present study, the BAH showed a relatively high SEM (6.68) and the mean scores were significantly different (p = 0.02) between the test and retest assessments. To account for these results, it is possible that the BAH test was physical demanding for the junior rugby players resulting in variability of the scores (Tsigilis et al., 2002).

Of interest were Eurofit tests which yielded low relative reliability values in the sample studied. The three tests included the PLT (ICC = 0.59), FBT (ICC = 0.51) and the SHR (ICC = 0.60) tests. The wide CIs in the calculated ICCs values for these tests question the reliability and the usefulness of these tests in assessing corresponding aspects of physical fitness in Zimbabwean junior rugby players. However, these findings were consistent with reports from other studies (Fjørtoft, 2000; Tsigilis et al., 2002). Tsigilis et al (2002) reported ICC values of 0.57 for the PLT test. Fjørtoft (2000) reported low reliability values for the FBT with a correlation of 0.43 Fjørtoft et al. (2011) reported an ICC value of 0.69 for the SHR test in 5- to 12-year-old Norwegian children. In spite of the consistent results with other studies, replicate future studies with larger samples may be needed to establish the reliability of these tests in Zimbabwean junior rugby players. Although the importance of balance (measured by the FBT), running speed and agility (measured by the SHR) and upper-limb coordination and reaction speed (measured by the PLT) can never be argued for rugby players, it is possible that these tests need modifications when further use is required in junior rugby players.

Limitations of the study

The results of this study should be interpreted cognisant of a number of important limitations. Although we found high ICCs for the majority of the Eurofit test items, our results lack the strength of generalisability to all junior rugby players in Zimbabwe. This was mainly because of limited participation of schools in the study. Although all the junior rugby players in the selected schools were invited to participate, much of the attrition of the sample size was caused by lack of parental support for the players to participate in the study. In addition, the timing for data collection could have influenced the sample size. This study was conducted during the competitive rugby season. This marks the time when coaches are extremely busy with the first team players. Cognisant of these limitations, the results of this study should be interpreted cautiously for other junior rugby players either playing in the SESRL from the private schools or outside Zimbabwean context. It suffices to consider this study as a pilot study providing baseline information on the reliability of the Eurofit test battery in junior rugby players in Zimbabwe. There is need for future replicate studies with large sample sizes generated from a random selection of all ‘elite’ junior rugby players from the schools participating in the SESRL in Zimbabwe. However, future studies using ‘elite’ junior rugby players may need to be considerate of the time to collect data. It may be ideal to conduct related future studies during the

pre-or post-season. In addition, future studies may consider reducing the training load, approximately by 50%, for 1–2 weeks before the measurements and plan a break in training for 1–2 days before the tests.

Conclusion

Numerous studies have been conducted validating the Eurofit test battery. However, few of these are in schoolboy rugby athletes from low-resource settings in Africa. Therefore, an attempt to address this problem through Zimbabwean rugby players seems scientifically interesting and offers great prospects, for example, the development of standards for this population of athletes in the future. Cognisant of the study limitations, this study pragmatically showed the possibility of evaluating the seven-day test-retest reliability of Eurofit test items during the in-season period among elite schoolboy rugby players from a low-resourced setting such as Zimbabwe. The following test items such as bent arm hang test, handgrip test, sit and reach test, standing broad jump test, and sit-up test can be recommended for reliably evaluating aspects of physical fitness in junior rugby players in Zimbabwe whilst others (Plate Tapping test, Flamingo Balance Test, and Shuttle Run test) still need consideration and test modification.

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