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VISCOELASTIC PROPERTIES OF LOWER EXTREMITY MUSCLES AFTER ELITE TRACK CYCLING SPRINT EVENTS: A CASE REPORT

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Abstract Sprint cycling events require a high level of anaerobic capacity and, therefore, may affect peripheral fatigue throughout exercise-induced muscle damage. In fact, those alterations might decrease power generation. This study was performed on a 23 years old male elite track cyclist taking part in a sprint event. The measurements included power output (W) and cadence (rpm), lactate concentration (La⁻), heart rate (bpm), Rating of Perceived Exertion scale and viscoelastic properties analysis. The present study has shown a new approach to monitor the muscle properties of the lower extremity after 200 m flying start and repeated sprint races. Therefore, we hypothesized that repeated sprint races might lead to alterations in viscoelastic properties of lower extremity muscles. In track cycling, especially in sprint events, these variations may lead to increased muscle fatigue. Furthermore, training control and monitoring related to the assessment of muscles properties can be a source of counteracting injuries and relieving fatigue.

Key words viscoelastic properties, muscle stiffness, creep, 200 m flying, case report

Introduction

Sprint performance is dependent on maximal cycling power and is therefore susceptible to muscular fatigue (Martin, Davidson, Paradyjak, 2007). Sprint cycling performance is mainly based on anaerobic metabolism derived from phosphocreatine (PCr) which produces lactate. An increase in lactate accumulation may affect neuromuscular activity and power generation, causing peripheral alterations in muscle fatigue. Moreover, mechanical and morphological properties of lower extremity muscles may influence power production capabilities (Stafilidis, Arampatzis, 2007).

Sprint races are one of the highest performance events in track cycling. They require maximal power output and velocity generation (Klich, Krymski, Michalik, Kawczyński, 2018). S. Dorel et al. (2005) reported that elite 200 m

flying start events ranged between 10 s and 11 s, while in our previous study (Klich et al., 2018), elite track cyclists completed an averaged personal record below 10 s.

Previous studies have reported the negative effect of overloading as muscle degeneration (Kawczyński et al., 2015; Klich et al., 2018). Therefore, an objective research protocol should be used to assess viscoelastic and biomechanical properties in order to prevent the risk of overloading and injuries. Myotonometry is a reliable tool for assessing the viscoelastic properties of muscles (Kawczyński et al., 2018; White, Abbott, Masi, Henderson, Nair, 2018). In previous studies, myotonometry was used to assess muscle stiffness, elasticity and muscle tone (Davidson, Bryant, Bower, Frawley, 2017). Moreover, it provides many quantitative data about muscle belly and tendon stiffness after fatigue (Viir et al., 2007).

To the best of our knowledge, no study to date has used the viscoelastic properties of the lower extremity muscles after a 200 m flying start and repeated sprints. These observations may provide a crucial understanding of injury prevention, recovery protocols, and physical therapy treatment. Thus, the viscoelastic properties of lower extremity muscles should be investigated after repeated sprint events.

Methods

Study design

An observational case study involved six repeated myotonometry measurements, namely: (1) before; (2) after a 200 m flying start; (3–6) following each sprint. Viscoelastic properties of lower extremity muscles (e.g. muscle tone, stiffness, decrement, relaxation time and creep) were investigated in anterior thigh muscles, hamstrings, tibia muscles, and cuff muscles on the right (dominant) side. The participant read and signed an informed consent form approved by the University Research Ethics Committee.

Participant

An elite track cyclist (age 23 years; body height 176.2 cm; body weight 85.8 kg; BMI 27.6 kg·m⁻²) participated in the study. The subject was a member of the National Track Cycling Team specializing in sprint events. The participant was a medalist in international-level track races with a training experience of 11 years. The subject had not suffered from an injury or pain within the past six weeks.

Experimental procedures

The experiment was prepared during a class 1 international event (men's sprint), where the subject started in a 200 m flying start and four sprint races. Sprint races were divided into qualifying (one race), quarterfinal (one race), semifinals (two races) and finals (two races). During all races peak and averaged power output (PO_{max} and PO_{mean}) [W] and cadence (C_{max} and C_{mean}) [rpm] were measured using PowerControl PC8 SRM (SRM GmbH, Germany). Rest HR was assessed using a Polar M400, heart rate monitor (Polar Electro, Finland). During the men's sprint events measurements of: a) peak and averaged heart rate (HR_{max} and HR_{mean}) [bpm]; b) blood lactate (La^-) [mmol·l⁻¹] (Lactate Scout, SensLab GmbH, Germany); c) Borg rating of perceived exertion (RPE) – 20 point scale; d) viscoelastic properties of the muscles (muscle tone, stiffness, decrement, relaxation time and creep) (Myotonometer; MyotonPro, Myoton Ltd, Estonia); were taken at rest and in the 3rd minute after each race. Time breaks between each stage were: 1) qualifying (200 m flying start) – quarterfinal (sprint 1) – 1st semifinal (sprint 2):

two hours; 2) 1st semifinal race (sprint 2) – 2nd semifinal race (sprint 3): 40 minutes; 3) 2nd semifinal race (sprint 3) – 1st final race (sprint 4): 1 hour.

A handheld Myotometer device was used to measure the lower extremity muscles viscoelastic properties (muscle tone, stiffness decrement, relaxation time and creep). Myotonometry measurements were made on the dominant lower extremity (right) at 23 reference points, including the anterior thigh muscles (points 1–7): rectus femoris (points 1–2); tensor fasciae latae (point 3); vastus lateralis (points 4–6); vastus medialis (point 7); posterior thigh muscles (points 8–15): external hamstrings (points 8–11); internal hamstrings (points 12–15); tibia muscles (points 16–18): tibialis anterior (point 16); peroneus (points 17–18); and posterior cuff muscles (points 19–23); external gastrocnemius (points 19–20); internal gastrocnemius (points 21–22); and soleus (point 23) muscles (Klich et al., 2018). For this study, three measurements at each reference point were performed, and the mean calculated. Measurement for one reference point took about 5 sec, while the total examination time was less than 2 min.

Results

The highest PO_{max} and PO_{mean} were observed during the 200 m flying start and sprint 4 (1973 W; 1904 W; 1172 W and 1124 W, respectively). C_{max} reached the highest value in sprint 4 (133 rpm), while C_{mean} during the 200 m flying start and sprint 2 (103 rpm and 104 rpm). The subject reached the highest HR_{max} noted during the 200 m flying start and sprint 2 (195 bpm both), and HR_{mean} in sprint 2 and 3 (184 bpm both). The highest La^- was observed during the 200 m flying start and sprint 4 (15.9 mmol·l⁻¹ both). RPE increased during all starts, reaching the highest in sprint 4 (19) (Table 1).

Table 1. Power output, cadence and physiological parameters after men's sprints

Variables	Rest	200 m	Sprint 1	Sprint 2	Sprint 3	Sprint 4
PO_{max} [W]	–	1,973	1,632	1,778	1,668	1,904
PO_{mean} [W]	–	1,172	1,034	1,045	1,103	1,124
C_{max} [rpm]	–	129	124	126	129	133
C_{mean} [rpm]	–	103	100	104	102	94
HR_{max} [bpm]	–	195	186	195	191	189
HR_{mean} [bpm]	70	182	178	184	184	177
La^- [mmol·l ⁻¹]	1.5	15.9	13.3	13.8	14.5	15.9
RPE	6	11	15	17	18	19

Abbreviations: PO_{max} = maximal power output [W]; PO_{mean} = mean power output [W]; C_{max} = maximal cadency [rpm]; C_{mean} = mean cadency [rpm]; HR_{max} = maximal heart rate [bpm]; HR_{mean} = mean heart rate [bpm]; La^- = lactate concentration [mmol·l⁻¹], RPE = Rating of Perceived Exertion.

The average muscle tone and stiffness increased after the 200 m flying start and sprint 1. The highest increase in tone observed in the hamstrings (200 m – 33.6%) and cuff (sprint 1 – 38.0%), while stiffness in hamstrings (200 m – 36.0% and sprint 1 – 47.7%). In sprint 2 we observed a decrease in muscle tone (an average of 19.0%) and stiffness (an average of 24.4%). In the next sprints (sprint 3 and 4) we observed the highest increase in muscle tone and stiffness in the tibia (tone – 20.4% and 24.6%; stiffness – 28.5% and 31.3%), and decrease in stiffness (13.6% and 15.0%). The highest decrement was observed in 1st, 3rd and 4th sprints, especially in the anterior thigh (36%; 39% and 52%, respectively) and tibia muscles (33%; 45% and 57%, respectively) (Figure 1a–c). The average

relaxation time and creep decreased after the 200 m flying start and sprint 1. The highest decrease in relaxation time and creep observed in the hamstrings (R – 31.6% and 44.2%; C – 31.3% and 45.0%, respectively) and tibia (R – 31.1% and 43.0%; C – 30.1% and 44.1%, respectively). The relaxation time of the hamstrings increased (sprint 2–4) (12.4% and 19.4%, respectively), however, decreased in the tibia (15.7% and 20.9%, respectively). The creep decreased in both muscle groups (Figure 2a, b).

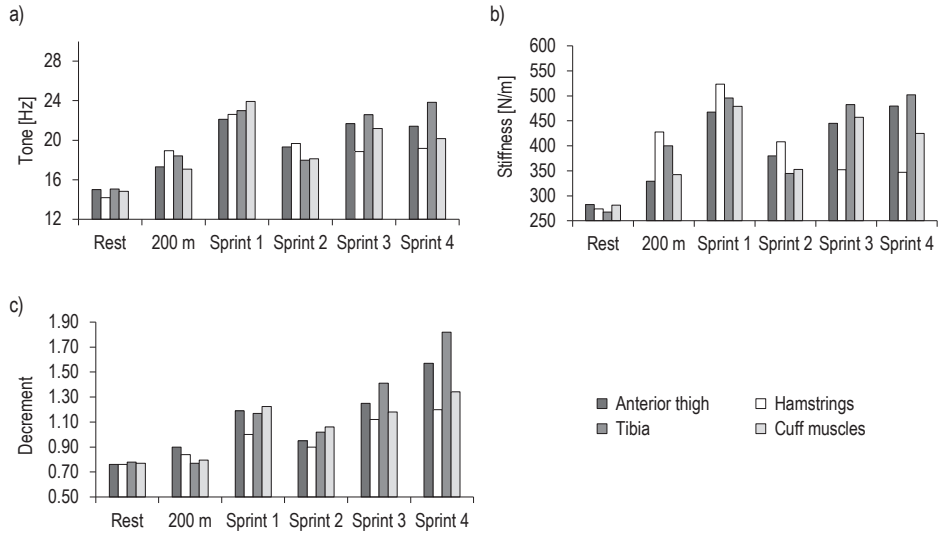


Figure 1. Muscle tone [Hz] (a), stiffness [N/m] (b) and decrement (c) after men's sprint

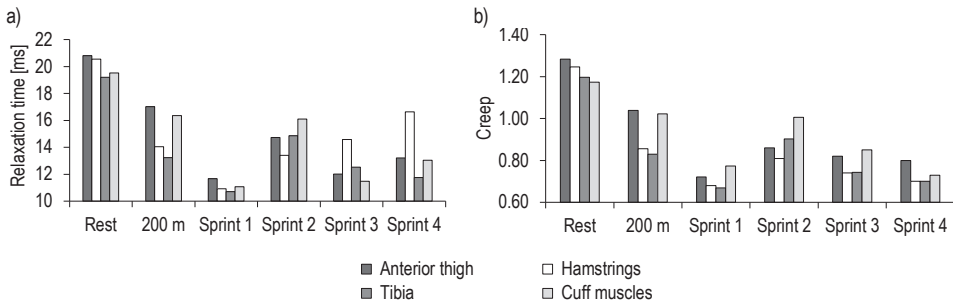


Figure 2. Relaxation time (a) and muscle creep (b) after men's sprint

Discussion

Experimental measurements have demonstrated that the 200 m flying start race had a considerable impact as a substantial increase in muscle tone, stiffness, and a decrement in lower extremity muscles, especially in the hamstrings and tibia muscles. However, an increase in muscle tone, stiffness, and a decrement in the tibia muscles was observed after subsequent sprints. This event had the opposite result in muscle relaxation time and creep.

J. McDaniel et al. (McDaniel, Behjani, Elmer, Brown, Martin, 2014) have reported that during maximal isokinetic cycling at 120 rpm, 49% of the power on the pedals was produced by the knee, 32% – by the hip, 9% – by the ankle, and transferred across the hip. Moreover, J.C. da Silva et al. (2016) observed that the quadriceps muscle and cuff muscle obtained the highest activity during cycling. Furthermore, the hamstrings can be activated during an increase in pedal rate. After the 200 m flying start and the 1st sprint, there was an observed increase in muscle tone and stiffness, while after the 2nd sprint a decrease in those parameters was found. The highest stiffness rate was observed in the hamstrings. Additionally, in sprints 3 and 4 a greater muscle stiffness was obtained, except for the hamstrings. R. Viir et al. (2007) reported a relationship between muscle tone and stiffness in the trapezius muscle. Those observations should be considered based on pedal stroke. Simultaneously an increase in anterior thigh stiffness is related to the propulsion phase, while during the downstroke phase the hamstrings and cuff muscles reach the highest stiffness (Dorel et al., 2005). The highest increase in tibia muscle stiffness, as well as a decrease in relaxation time and creep after the 3rd and the 4th sprint was caused probably by a high range of action (all the range) and peak activity angle (280°) (Ryan, Gregor, 1992). A. White et al. (2018) found a correlation between relaxation time and creep of lower lumbar erector spinae muscle. From the biomechanical point of view, as muscle stiffness increases, relaxation time shortens, and less degree of creep is needed. Furthermore, stiffness is inversely proportional to relaxation time, because the stiffer the tissue, the shorter time is needed to recover. According to C.R. Abbiss et al. (Abbiss, Peiffer, Laursen, 2009), a sprint cyclist's pedal rate should be about 100–120 rpm, as it reduces neuromuscular fatigue. In our opinion, sprint tactics and increased muscle fatigue could influence the alterations in viscoelastic properties. Increase in pedaling rate could be associated with greater activity of the vastus medialis, medial hamstrings and the calf muscles. The last sprint (4th) was followed by a maximal cadence of 133 rpm, while the mean cadence was 94 rpm. T. Takaishi et al. (Takaishi, Yasuda, Ono, Moritani, 1996) suggest that lower pedaling rate may lead to worse blood flow and venous return in the muscles. An increase in decrement could confirm our observations, because this parameter reflects muscle elasticity. Biomechanically, decrement is inverse proportional to elasticity. A. White et al. (2018) have reported a positive correlation between muscle stiffness and decrement. In our opinion, alterations in viscoelastic properties in the tibia muscles are related to increased fatigue of the anterior thigh and cuff muscles (Klich et al., 2018).

Conclusion

The 200 m flying start and repeated sprint races appear to affect the viscoelastic properties of lower extremity muscles in track cyclists. The increase of muscle tone, stiffness and decrement is followed by a decrease in relaxation time and creep. This study has proved that the muscle fatigue mechanism is related to alterations in viscoelastic properties. Moreover, fatigue mechanisms might influence muscle outcomes, e.g. muscle activation, recruitment and fibers type. This research presents the individual results of a single athlete, yet the main findings of the study could be useful information in programming specific workouts and recovery sessions.

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REPRESENTATIVENESS OF OFFENSIVE SCENARIOS TO EVALUATE PERCEPTUAL-COGNITIVE SKILLS OF WATER POLO PLAYERS

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Abstract The aim of this study was to trial several attacking offensive sequences as representative for further use in research on the perceptual-cognitive skills of water polo players. Elite water polo coaches were presented with separate test film sequences encompassing 80 structured water polo offensive plays. Each clip was approximately 6 s–7 s long with an inter-clip interval of 5 s–10 s, where a red dot was displayed on-screen at the start of the clip to indicate the area of first appearance of the ball. The order of presentation of the video clips was counterbalanced and randomly determined. The criteria were scored on a 5-point Likert-type scale. From the 80 clips presented, only 56 showed high agreement ($W = 1$; $p < 0.05$) and internal consistence reliability between the expert observers ($\alpha = 0.980$; $p < 0.05$). Furthermore, a very high reproducibility ($Z = 0$; $p = 1$) was obtained between viewing sessions. The results obtained determine that 56 offensive scenarios were representative of the water polo game and as such may be useful in evaluating the perceptual-cognitive skills of the players.

Key words decision-making, Attacking Game Scenarios, reliability, Water Polo

Introduction

Most team sports provide an outstanding stimulating environment where players are required to make accurate and fast decisions due to time, space and opponent constraints (Williams, 2000). In water polo, as in most team sports, along with a proficient execution of motor abilities, perceptual-cognitive skills and tactical knowledge (e.g. declarative knowledge) are of utmost importance to achieve expert performance (Williams, Davids, 1995; Américo et al., 2018). Perceptual-cognitive expertise has been defined as the ability of an individual to locate,

identify and process environmental information, integrate it with existing knowledge and current motor capabilities, and select and execute appropriate responses (Marteniuk, 1976).

Researchers have identified several perceptive-cognitive skills that could influence sport performance, e.g. pattern recognition (Williams, Hodges, North, Barton, 2006; Williams, Ford, Eccles, Ward, 2011), postural cue usage (Williams, 2002; Savelsbergh et al., 2002; Abernethy, Zawi, 2007), situational probabilities (Williams et al., 2011; Farrow, Reid, 2013) and visual search behaviour (Williams, Davids, Williams, 1999). Moreover, expert players seem to perform more efficiently than novices in a wide range of anticipatory and decisional tasks (Mann, Williams, Ward, Janelle, 2007; Williams, Paul, Julian, Nicolas, 2008). In measuring and understanding the perceptual-cognitive skills underpinning anticipatory skills in sports, a laboratory-based environment (using video or static slides presentations) has mostly been used, due to its inherent experimental control, repeatability and safety (Zeuwts et al., 2016). Those protocols significantly rely in recall and occlusion paradigms that, despite being sensible to detect differences in players expertise level, neglect response times, inhibit correctional perceptive information (static slides) and push reliance on cognitive processes, i.e. video-based trials (Mann et al., 2007).

The abovementioned disadvantages are a direct consequence of a disruption in the sport perception-action cycle, encouraging informational cues and pattern reliance that may not necessarily be used, and employment of different processes in decision making (Abernethy, Katherine, Jerry, 1993; Roca, Williams, Ford, 2014; Zeuwts et al., 2016). These findings are supported by L. Zeuwts et al. (2016) who stated that “the disruption of our natural perception-action cycle might lead to differences in the amount and nature of the information collected, and/or in the way this information is further processed”. Concerning the experiment protocol, evidence was found that in goalkeepers, gaze and visual search behaviours function differently, particularly when needing to fix the ball earlier and for a longer during *in situ* condition with interception vs with movement, and when predicting the penalty kick direction during a video simulation with movement vs with visual reports (Dicks, Button, Davids, 2010).

Despite this lack of environmental validity, video-based trials still prove to be a valid and useful tool in evaluating perceptive-cognitive skills compared to static slides (Casanova, Garganta, Oliveira, 2012), especially when used to distinguish a player’s expertise level (North, Ward, Ericsson, Williams, 2011; McRobert, Ward, Eccles, Williams, 2011). For example, it was found that skilled cricket batters were better in anticipation and employed a more refined visual search strategy than less-skilled counterparts using video-based simulations (McRobert et al., 2011).

To accomplish effective video-based perceptual-cognitive skill protocols, firstly, representative and reproducible sport tasks are presented to the athlete, then, the same tasks are used to detect, identify and measure the process-tracing elements through registering visual reports (monitoring eye movements and task manipulations) and, finally, process-tracing element learning is investigated retrospectively and prospectively concerning expertise development (Ericsson, Smith, 1991; Williams, Ericsson, 2005). In addition, to validate representative tasks that could be used to evaluate tactical game understanding, the consensus of six expert level teachers/coaches was collected in the development of a Game Performance Assessment Instrument (GPAI; Oslin, Mitchell, Griffin, 1998). This is a useful and reliable tool to assess players’ skill execution and tactical awareness with and without a ball (Santos, Dias, Mendes, Coelho-e-Silva, 2016).

Concerning water polo, few studies have investigated player perceptual-cognitive skills. In a study by E. Kiourmourtzoglou, T. Kourtessis, M. Michalopoulou and V. Derri (1998), the results evidenced that elite water polo players showed better scores than novices on decision-making, visual reaction time and spatial orientation.

Similarly, L. Quevedo-Junyent, J. Aznar-Casanova, D. Merindano-Encina, G. Cardona and J. Solé-Fortó (2011) found that elite players achieved better dynamic visual acuity scores, and the results also improved for some combinations of speed, contrast and trajectory. Undoubtedly, in water polo, the aquatic medium is a major limitation to implement environmental trials, being a difficult to not only to recreate, but also to use electronic equipment. Therefore, the use of video-based trials seems a reasonable, valid and cost-effectiveness methodology to evaluate perceptual-cognitive skills in water polo players.

As water polo related studies are scarce, there is a huge informational gap about the perceptual-cognitive skills underpinning anticipation ability and their relative importance in achieving success.

The main purpose of the current study then was to identify offensive scenarios that could be representative in water polo for assessing the levels of the perceptual-cognitive skills underpinning the anticipatory abilities of players. To accomplish that aim, habilitated and experienced water polo coaches were invited to comment on the representativeness of selected offensive scenarios.

Method

Participants

The representativeness of selected offensive scenarios was determined by a panel of 10 licenced water polo coaches with post-graduate Physical Education qualifications and at least 10 years of active training experience. The study was approved by the Ethics Committee of the host University (protocol number CEFAD.02.2019) and all procedures conducted in accordance with the Declaration of Helsinki (1996) norms. Coaches volunteered to participate and filled in an informed consent form.

Match scenarios

The coach panel watched 80 match clips from the final game of a national mens water polo cup match. The clips randomly represented different offensive game situations, in both even play and temporary numerical superiority. To support identical match characteristics, a shot clock with the official remaining attack time was superimposed in the middle of the clip, but avoiding conflicting visual perception of the ball's flying trajectory (Figure 1). Each trial was filmed from both 10 m behind and 5 m above the goal with two cameras (Rollei® 5S FHD, 1920 × 1080 pixels, 60 Hz framerate and 175° capture angle). The elevated filming position allowed presentation of some elements of visual depth.

Windows Movie Maker® and Wondershare Filmora® version 7.8.0 software were used to edit the game recordings into 80 clips. After display of the clip number, a red dot would appear on-screen marking the starting point of the ball, with the screen turning black when the offensive scenario had finished. Each clip lasted 6 s–7 s and the questionnaires were filled in during the 5 s to 10 s intervals between clips. To define clip representativeness, coaches viewed the entire clip, inclusively of the outcome of the play, i.e., shot to goal, shot to goalkeeper defence or out, defensive steal, defensive block, pass to centre-forward with, or not, exclusion of defensive centre-back or offensive foul.

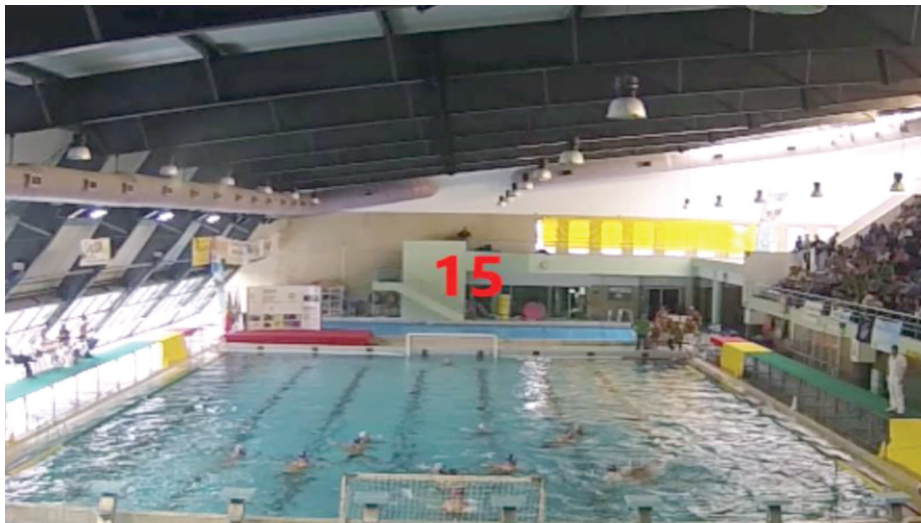


Figure 1. Frame of one offensive scenario presented in the video

Procedures

All the clip evaluations were conducted in a classroom at the host University, with scenarios being projected (model VPL-EW 255, maximum resolution 1,600 × 1,200 pixels with 3.200 ANSI Lumens of brightness and a contrast rate of 2700 : 1) from a laptop onto a white screen (2 × 3 m). The clip representativeness was scored on a 5-point Likert-type scale questionnaire, in which 1 means “total disagreement” and 5 “total agreement” with the representativeness of the observed offensive pattern. Likert-scales have proven to be valid and reliable psychometric scale to measure attitudes and is commonly used in social studies and marketing research (Hartley, MacLean Jr., 2006; Dawes, 2008), and have been used in perceptual-cognitive expertise in sport related research (Williams et al, 2006). The clip presentation was counterbalanced and randomly determined, during both evaluation meetings (one month between them). To familiarize coaches with the scenarios and the protocol, two additional clips were presented prior to the main assessments.

Data analysis

Descriptive statistical analysis was used to examine the valid values of the 5-point Likert-type scale, and Kendall's coefficient of concordance (W) was applied to test agreement between the observers. Cronbach's Alpha (α) was used to test the internal consistency reliability between the observers, and nonparametric Wilcoxon Signed Rank tests (Z) allowed verification of the construct validity (observers re-test). The Statistical Package for Social Sciences v 24.0 (SPSS Inc., Chicago, IL, USA) was used in all statistical procedures, and a statistical significance of $p < 0.05$ was set at for all tests.

Results

From the 80 water polo clips viewed, 24 were excluded when one or more coaches expressed “total disagreement” or “disagreement” with that specific offensive event. Therefore, a total of 56 clips were accepted for ongoing analysis, with the representativeness of the offensive game events being concordant among the observers in all the clips accepted ($W = 1, p < 0.05$). The internal consistency reliability between the observers was maintained ($\alpha = 0.980; p < 0.05$). Finally, regarding the construct validity of the clips, when the expert coaches watched the scenarios for a second time, the values of the 5-point Likert-type scale were strongly reproduced ($Z = 0; p = 1$; Table 1).

Table 1. Mean valid values of the 5-point Likert-type scale (\pm SD) pointed by the coaches, in both moments of evaluation

Coach	Test	Re-Test
1	4.98 \pm 0.134	4.98 \pm 0.134
2	4.98 \pm 0.134	4.98 \pm 0.134
3	4.98 \pm 0.134	4.98 \pm 0.134
4	4.96 \pm 0.187	4.96 \pm 0.187
5	4.98 \pm 0.134	4.98 \pm 0.134
6	4.98 \pm 0.134	4.98 \pm 0.134
7	4.98 \pm 0.134	4.98 \pm 0.134
8	4.96 \pm 0.187	4.96 \pm 0.187
9	4.98 \pm 0.134	4.98 \pm 0.134
10	4.98 \pm 0.134	4.98 \pm 0.134

Discussion

Accepting that offensive clips are a useful tool to evaluate perceptual-cognitive skills under controlled laboratory trials (Williams et al., 1999), the main purpose of the current study was to establish representative water polo offensive scenarios for further use in perceptual-cognitive skills research. A panel of 10 expert coaches agreed that 56 clips were representative of the water polo game and, since the clips were taken from a major national competition final, all game characteristics were validated. It should be noted that player decisions in the clips would not always be the most appropriate in the offensive plays (as happens in any other sport).

In water polo, four main game phases are considered: counterattack, even play, transition, and power play. Since the transition phase was not addressed in this study, and no counterattack occurred, all the remaining game phases were retracted in the observed scenarios. In closed matches (up to a three goal difference between the winning and losing teams) of a water polo world championship, it was observed that the team’s ability to gain exclusion fouls and score during temporary numerical superiority (power play) defined the winner and the loser (Lupo, Tessitore, Minganti, Capranica, 2010). These authors also stated that the centre-forward position had a determinant role, so the most direct offensive solution is to unbalance the opposition’s defensive game play and then make a pass to the centre-forward. Moreover, a tendency was found for higher level teams to finish an even play situation with a centre-forward action, rather than perimeter players obtaining a power play situation or a penalty (Lupo et al., 2012). Moreover, E. Mirvic, F. Rasidagic, N. Nurkovic, H. Kajmovic, C. Lupo (2019) reported on

the outcomes of the Brazilian Olympic Games women's water polo matches, and noted that close and unbalanced games were decided by non-specific plays, and only a few by technical and tactical factors.

Power play and counterattack efficiency had been considered determinant in defining winning and losing teams when the match is close or unbalanced (Canossa, Garganta, Argudo, Fernandes, 2009; Saavedra, Escalante, Madera, Mansilla, Garcia-Hermoso, 2014). Corroborating the above mentioned observations, in evaluating 88 games from the Spanish Professional Water polo League to identify offensive performance indicators that best determined a match status (winning, losing or drawing), it was found that the attack outcome most determined match status and, for games with penalties, counterattack shots and counterattacks determined match status (Ordoñez, Pérez, González, 2016). Another central aspect of the game is goalkeeper efficiency, considered determinant for winning/losing outcomes in major national competitions (Escalante et al., 2011; Saavedra et al., 2014). Accordingly, a good strategy may lie in fatiguing and misplacing the goalkeeper, opening opportunities to efficiently score.

The use of video scenarios in evaluating such a conclusion would allow video editing to occlude, speed up, slow down, add informational or irrelevant cues, tied with other measurements (e.g. eye movement registration and verbal reports) to allow a global understanding of the players' perceptual-cognitive skills in several decision-making tasks (Casanova et al., 2012), promoting a better understanding of the main discriminate variables of successful and unsuccessful water polo teams. In addition, video-based trials can be very useful due to their repeatability, safety and experimental control (Abernethy et al., 1993; Ali, 2011; Vickers, 2007; Casanova et al., 2012). Concerning further perceptual-cognitive expertise evaluations, the clip duration was maintained between 6 s and 7 s as athletes can accurately recall complete sequences after a 0.5 s–10 s task (Eriksson, Simon, 1999).

In conjunction with scenes, temporal occlusion has been used in some studies for decision-making tests in which players were required to anticipate the near future action that was executed at the end of each video clip (Williams et al., 1994; Casanova et al., 2013). The methodological technique used to occlude the scene (i.e. information) at a specific time in a critical event of information extraction by players (e.g. before the moment that the player will touch the ball and will continue the action), allows the researchers to evaluate player abilities to recognize and use *de postural* cues, so differencing expertise across skill groups (Williams et al., 2011).

Some caution is required when developing task designs for evaluating perceptual-cognitive skills, namely in the control of variables, the outcomes and test validity, for understanding functional human behaviour (Causar, Barach, Williams, 2014). Some research limitations should be pointed out too, as the level of Portuguese Water polo is below many countries that have good results in European and World competitions. Despite no study being conducted to assess the differences in declarative knowledge between water polo players and coaches in Portugal and other countries, these differences likely exist. The players would also be evaluated in a context with no physical fitness or fatigue, so it is difficult to determine how such differences in cognition and gaze control affect performance.

Nevertheless, and as stated above, this framework allows a great experimental control, repeatability and safety control (Abernethy et al., 1993; Ali, 2011; Vickers, 2007; Casanova et al., 2012). Furthermore, the representative offensive clips defined in this study may open a bridge for a major understanding of the water polo game and distinguish expert from non-expert water polo players.

This study suggested that 56 offensive scenarios were indeed representative of the water polo game and as such may be useful for ongoing evaluation of perceptual-cognitive skills of water polo players. Moreover, this powerful and useful tool may allow water polo coaches to analyse and evaluate the anticipatory ability of their

athletes in a control environment. In addition, and of utmost importance is the understanding of parallelism between laboratory results and real game performance in a water polo match.

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Author contributions statement

This research is based on data collected for postdoctoral work by FC. FT and RJF assisted with A. RP, SC, MP and RB assisted with B. IT, SG-V and RJF assisted with D.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EFFECT OF CHAIR AEROBICS ON QUALITY OF LIFE IN SEDENTARY OBESE INDIVIDUALS

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Abstract Background: A sedentary lifestyle is associated with various negative health outcomes, including obesity. Aerobic exercise is shown to have beneficial effects on all body systems. The purpose of the present study was to demonstrate the effect of chair aerobics as a light to moderate intensity exercise on the quality of life of obese sedentary individuals.

Objectives: Objectives of the study were to improve the physical function and the quality of life in obese individuals in a sedentary working environment in order to improve the energy levels and reduce fatigue.

Material and methods: An experimental study was conducted among sedentary obese individuals. Subjects were screened pre-intervention using OSPAQ, BMI etc. Chair aerobics was given in the form of group therapy as a light to moderate intensity exercise programme. Quality of life was assessed post intervention by assessing self esteem and activity levels and physical functioning through QLQ II and SF 36 questionnaires.

Results: The study showed statistically significant differences in BMI ($p < 0.0001$), self esteem and activity levels ($p < 0.0001$), energy levels and general health ($p < 0.0001$).

Conclusion: Chair aerobics showed a significant effect on the quality of life of sedentary obese individuals with improved levels of physical functioning, increased energy levels and reduced fatigue levels.

Key words chair aerobics, sedentary, obesity, physical activity, workplace

Introduction

Sedentary behaviour is defined as "any waking behaviour characterized by an energy expenditure less than a 1.5 metabolic equivalent of task (MET) while in a sitting or reclining posture" (Straker, Coenen, Dustan, Gilson, Healy, 2016). The metabolic equivalent of task (MET) is the energy expended for an activity and is defined as the ratio of the energy expended during quiet sitting (Straker et al., 2016).

Sedentary behaviour thus refers to a distinct class of behaviours either performed while sitting or reclining with low energy expenditure (Straker et al., 2016).

Sedentary behaviour is conceptually different to “physical inactivity”, which is defined as “performing insufficient amounts of moderate to vigorous intensity physical activity, not meeting the specified physical activity guidelines” (Straker et al., 2016). Moderate intensity physical activity is defined as >3 to <6 METs, and vigorous intensity activity as >6 METs. Light activity is >1.5 to <3 METs. A broad range of behaviours fall within this band.

Sedentary lifestyle has been shown to be detrimentally associated with degenerative cardiometabolic outcomes (such as cardiovascular diseases, diabetes and obesity), musculoskeletal problems, mental ill-health, and poor quality of life.

A sedentary lifestyle is also associated with an increase in BMI over time, thus leading to obesity (Straker et al., 2016). Reducing sedentary behaviours could help prevent an increase in BMI and thereby reduce the occurrence of obesity (Mitchell et al., 2014). Physical activity has been shown to reduce stress and anxiety traits and to improve physical self-perception and mental well-being (“Effect of aerobic fitness on the physiological stress responses at work – PubMed-NCBI,” n.d.). Aerobic fitness also helps to reduce stress responses and improves an individual’s capacity for coping with stress (“Effect of aerobic fitness on the physiological stress responses at work. – PubMed-NCBI,” n.d.). Chair Aerobics are aerobic exercises performed while sitting in a chair, which include upper and lower body movements led by an instructor while listening to music and sitting in a straight-back chair (Robinson, Masud, Hawley-Hague, 2016). Chair based exercises have been shown to have a beneficial effect at maintaining or promoting independence and mobility in older people and also in patients post CABG (Anthony, n.d.; Thapa, Pattanshetty, 2016). Compliance to chair based programs is generally better than that of standing or dynamic exercise, especially amongst low baseline levels of fitness and function. Chair based exercise has specific benefits as a training method as it stabilizes the lower spine by providing a fixed base, and it facilitates a greater range of movement by providing points of leverage and support; it minimizes load-bearing and reduces balance problems in those with particularly poor mobility (Robinson et al., 2016).

In certain professions, physical activity levels at work are low while sedentary behaviour is high. This largely depends on the function of the occupation (white-collar vs. blue-collar). A sedentary lifestyle leads to various diseases and disorders that may lead to deleterious health outcomes of the patients. A sedentary lifestyle is also associated with reduced quality of work and increased stress levels in individuals, affecting their overall psychosocial well-being. A sedentary work environment is associated with reduced levels of physical fitness along with various musculoskeletal conditions and psychosocial stress. Chair aerobics is an alternative to dynamic exercises while working, for individuals with a sedentary work environment or sedentary lifestyle.

This study thus focuses on increasing the levels of physical fitness, improving the quality of life and reducing the stress and anxiety levels in individuals with a sedentary nature of work. Previous research focuses on various issues related to sedentary work behaviour and thus studies which will address the decrease in quality of work due to sedentary behaviour are required.

Methods

This study was a pre/post experimental design with a selection of employees working in an institute, randomly selecting employees based on inclusion and exclusion criteria. The data was collected from individuals or employees with a sedentary work environment i.e. sitting for >3h/d (according to OSPAQ) during the study period or extending for 6 months. Ethical approval for the study was granted by the Institutional Ethical Committee. Both genders aged 25–45 willing to participate in the study were considered for selection. An informed consent form was filled in by

the participants. Those with a BMI more than 30 and those who were unable to do weight bearing exercises were selected.

Subjects having a history of any psychological conditions, congenital or genetic disorders or with major abdominal or cardiovascular surgeries were excluded from the study. Statistically analysis was done using "InStat" for Windows v3.06. Intra group comparisons were done by applying a "Paired t-test" to the pre- and post-treatment values of the group for the BMI and SF-36 Questionnaire.

A Wilcoxon matched paired test was used on intra group analysis of non-parametric data (Moorehead-Ardelt Quality of Life Questionnaire II) (Moorehead, Ardelt-Gattinger, Lechner, Oria, 2003). Probability value $p < 0.05$ was considered statistically significant.

Procedure:

- a) subjects with a sedentary working environment were screened and selected on the basis of inclusion criteria;
- b) 53 Subjects were screened by assessing BMI, Occupational Sitting and Physical Activity Questionnaire (OSPAQ), and 36 subjects fulfilled the criteria;
- c) sedentary participants were selected on the basis of OSPAQ, at $>3\text{hr/day}$ due to their nature of work. QLQII and SF36 Questionnaire were filled in by these subjects;
- d) informed consent was taken from the participants. Each was explained the procedure of the study;
- e) warm-up exercises were given in the form of an active Range of Movement (AROM) for the Upper Limb and Lower Limb followed by a session of Chair Aerobics. A gradual increase in intensity and frequency was done according to the FITT principle. (Frequency, Intensity, Time, Type). The exercise session ended with stretching and relaxation (diaphragmatic breathing exercises) as a cool-down phase;
- f) each exercise was given for 30–45 min for 4 days/week over a period of 8 weeks;
- g) chair aerobics was given as a group therapy to all the subjects. The following exercises were given:
 - free neck exercises,
 - shoulder and elbow rotations,
 - wrist curls and rotations,
 - ankle toe movements,
 - spine flexion and extension,
 - spinal side rotation;
- h) initially, 5 sets of each exercise were given, gradually increasing it to 10 sets. Total time duration of warm up phase was 15 minutes;
- i) exercises included in the aerobic session:
 - marching with arm movement,
 - alternate hand and leg movements,
 - alternate arm and leg raise,
 - knee to chest,
 - v step,
 - claps on head,
 - marching in standing position,
 - hamstring curls,

- leg swings,
 - lunges,
 - knee to chest in a standing position;
- j) initially, low intensity exercise was performed, gradually increasing the speed of movements and thus their intensity. Total time duration of chair aerobics was 30–40 minutes Exercises included in the cool-down session:
- neck stretch,
 - forearm stretch,
 - triceps stretch,
 - pectoral stretch,
 - quadriceps stretch,
 - hamstring and ta stretch (the stretches were sustained from 10 seconds and up to 30 seconds. Total time duration of the cool down phase was 10–15 minutes);
- k) 25 individuals participated throughout the study for 8 weeks. There were 11 dropouts due to the work and deadlines to be covered by these employees;
- l) after the intended duration of treatment, the efficacy of the treatment protocol was observed;
- m) the data collection sheets were filled in post-test and assessed;
- n) statistical analysis was done with appropriate biostatistical tools.

Results

A total of 56 subjects with a sedentary lifestyle (OSPAQ > 3hr/day) were screened during the study recruitment period, out of which 36 were enrolled on the basis of inclusion criteria. 25 individuals completed the exercise training period. The results of the study were based on data collected for 25 subjects. The mean age of the subjects was 38 ± 7.03 years. The 25 subjects comprised 11 males and 14 females. Pre- and post-intervention outcomes were measured. There was a significant difference in BMI, at $p < 0.0001$. Also there was significant difference in self esteem and activity levels assessed by Moorehead-Ardelt Quality of Life Questionnaire, and a significant improvement was seen in all components.

Self esteem and self-image assessed by “Usually I feel...” was changed from “very badly about myself” to “very good about myself” ($p < 0.0001$). Interest in Physical activities developed from “not at all” to “very much” ($p < 0.0001$). Social contacts were increased probably due to the group exercises from none to some ($p = 0.0313$). Increased satisfaction with sex life was significant ($p = 0.0039$) and their outlook towards “between meal munching” (i.e. approach towards food) changed, and thus overeating was prevented after incorporating physical activity in their schedule ($p = 0.0313$).

Overall, the Self Esteem and Activity levels were considerably increased by including some form of physical activity in the sedentary working lifestyle of the obese individuals. Levels of Physical Functioning were improved significantly ($p = 0.0006$). Role Limitation due to Physical Health was reduced significantly ($p = 0.0014$). Role Limitation due to Emotional Health was reduced significantly ($p < 0.000$). Energy levels were improved and fatigue levels were reduced ($p < 0.0001$). Emotional Well Being of individuals was better ($p = 0.0184$) which is significant. Social Functioning was improved ($p = 0.0012$). Body pain was considerably reduced ($p = 0.001$) and General Health of the individuals was better than the pre-test ($p < 0.0001$).

Discussion

This study was conducted to evaluate the effect of chair aerobics on quality of life in sedentary obese individuals. A sedentary lifestyle is associated with various types of disorders. M. Castillo-Retamal and E.A. Hinckson (2011) suggest that now-a-days a sedentary activity level in the workplace is high due to a change in the nature of modern job functions, and thus physical activity in the workplace should be measured and intervention should be made to reduce the ill-effects of a sedentary lifestyle (a study by Jonathan A. Mitchell suggests that a sedentary lifestyle is associated with an increase in BMI over time and thus, an increase in BMI is associated with occurrence of various morbid health conditions).

Chair aerobics is a form of aerobic exercise performed while sitting in a chair or with the help of a chair, which includes rhythmic upper and lower body movements matching the beats of music. Chair aerobics is a low to medium intensity exercise in which the spine is stabilized by a fixed base of support compared to that of standing or dynamic exercises, which require a lot of stability (also chair aerobics facilitate a greater range of movement by providing points of leverage and support, it also minimizes load-bearing on joints while some postural muscles are relaxed; it also reduces balance problems in those with poor mobility and makes a great form of exercise while sitting).

The main aim of this study was to evaluate the effectiveness of chair aerobics on an improvement of quality of life of obese and sedentary individuals. The objectives of the study were to improve the physical fitness and quality of life in individuals with a sedentary working environment, to improve their energy levels by reducing fatigue levels in these individuals. 53 individuals participated in the study out of which 36 individuals fulfilled the selection criteria and 25 individuals continued their participation in the study for the 8 weeks. Subjects were screened by measuring their BMI and by measuring the hours they sit by Occupational Sitting and Physical Activity Questionnaire (OSPAQ) to rule out their sedentary nature of work. The 25 individuals comprised 11 males and 14 females. It was seen that the BMI of the females was higher than that of the males. A study entitled "Global Gender Disparities in Obesity: A Review" by Rebecca Kanter et al. supports this difference noted, by suggesting that in developing countries women are more likely to have a higher BMI than men.

The chair aerobics sessions were carried out 4 days per week for 8 weeks, when BMI was again measured. Along with BMI, QLQII and SF36 Questionnaire were also assessed. Outcome measures showed significant differences among BMI and the components of both the Questionnaires. This was confirmed using statistical analysis using a 'Paired t-test' and non-parametric Wilcoxon tests for intra group comparisons.

Within the intra group comparison, the pre-treatment BMI was 31.77 ± 3.23 and dropped to 30.31 ± 3.19 ($p < 0.0001$) which showed a small but significant decrease in BMI. Also, the Self esteem and Activity levels assessed by Moorehead-Ardelt Quality of Life Questionnaire, a significant improvement was seen in all components. Self esteem and Self-image, Interest in physical activities had improved. Social contacts increased probably due to the group exercises. Satisfaction from sex life increased and their outlook towards food as a way of providing nutrition increased. Thus, snacking between the meals was reduced and overeating was prevented. Overall, the Self Esteem and Activity levels were considerably better after including some form of physical activity in the sedentary working lifestyle of the obese individuals.

The levels of Physical Functioning improved significantly with $p = 0.0006$. Role Limitation due to Physical Health and emotional health reduced significantly. Energy levels improved and fatigue levels reduced with $p < 0.0001$. Emotional Well Being of individuals was better. Social Functioning improved. Body pain was considerably reduced and General Health of individuals was better than pre-intervention. Physical activity and exercise have a wide range

of health benefits. Studies show that physical activity can boost self-esteem, mood, quality of sleep and energy, and reduce the risk of stress, anxiety and various other disorders. According to research, regular aerobic exercise appears to boost the size of the hippocampus, thereby improving verbal memory and learning along with numerous physiological effects seen in various systems of the body. A study entitled "Health benefits of physical activity: the evidence" by Darren E.R. Warburton, suggests that an increase in energy expenditure from physical activity of 1,000 kcal (4,200 kJ) per week or an increase in physical fitness of 1 MET (metabolic equivalent) was associated with a mortality reduction of about 20%. An increase in physical fitness will reduce the risk of pre-mature death, while modest enhancements in physical fitness in previously sedentary people have been associated with large improvements in health status. Thus, exercise has numerous benefits and chair aerobics is one such new type of low to medium energy impact exercise. It makes use of energy by incorporating low to high energy as needed by modifying the intensity of the exercise with maximum amount of benefit during working hours in individuals who cannot specifically incorporate exercise in their day to day life due to their work schedule.

Incorporating exercise in the workplace will also address the stress and anxiety issues faced by employees. Presently, there is a lack of exercise and physical activity in various professions due to the digital and sedentary nature of our work. Perhaps, incorporating chair aerobics as a group or by using ear-phones by an individual can serve to fill that void of physical activity and help to enhance the benefits of physical activity and exercise in the workplace.

While considering chair aerobics, there is an increase in cardiopulmonary responses as well as other physiological changes. Stress and anxiety are reduced, and self esteem, body image and self-confidence improve with the help of chair aerobics. Exercise has numerous benefits on overall health and thus this could be used by individuals while at work to make individuals healthy and fit in all domains of life and prevent diseases and disorders.

Although the study duration was short and limited to a small sample size, it can be stated that chair aerobics with a low to moderate intensity reduces the BMI of individuals and has a positive impact on overall general health. A future study with a large sample size or RCT comparing effect chair aerobics with different treatment forms or dietary advice can be undertaken.

Conclusion

This study concluded that there was a significant effect of chair aerobics on the quality of life of sedentary obese individuals, with improved levels of physical functioning, increased energy levels, and reduced fatigue levels with much more added health benefits.

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Conflicts of Interest

The authors declare no conflicts of interest.

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DIGIT RATIO IN GROUPS OF SPORTING AND NON-SPORTING WOMEN AND MEN AND ITS RELATIONS WITH SOMATIC FEATURES AND MOTOR FITNESS

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Abstract The aim of the paper was to evaluate the digit ratio between groups of sporting and non-sporting women and men, and attempt to determine a value typical for athletes of each gender. Additionally, the aim was to evaluate relations of the digit ratio with both the somatic structure and motor fitness, which could then be used to improve on sports selection criteria.

The research material comprised 22 anthropometric measurements together with results of four motor fitness tests of students active in various sports disciplines. The control group comprised students who had never practiced sport. The sporting students showed significantly lower digit ratios compared to the control group of non-sporting students. Correlations between the digit ratio and features of the body structure were low. Both sexes recorded significant negative correlations between the digit ratio and handgrip strength, as well as with the long jump length.

Those with a lower value of the digit ratio had better predispositions to practicing sports.

Key words 2D:4D index, body build, motor fitness, sport

Introduction

The level of sports activity and the success at a sports are conditioned by many factors. One such factor is the somatic structure, which develops under the effect of endo- and exogenic factors as pre-natal development progresses. The digit ratio is one of the morphological features that can be prognostic for high sports achievements, developing at the early stage of ontogenesis between the 13th and 14th pregnancy week and under the effect of the sex hormones; androgens (Garn, Burdi, Babler, Stinson, 1975; Lutchmaya, Baron Cohen, Raggatt, Knickmeyer, Manning, 2004; Manning, Scutt, Wilson, Lewis-Jones, 1998). A low exposure of the foetus to uterine testosterone accompanied by a high concentration of estrogens, increases the value of the digit ratio making the digit structure

more feminine (ratio ≥ 1), and conversely, a high concentration of testosterone accompanied by a low concentration of estrogens lowers the digit ratio, which is characteristic for males (ratio < 1) (Hönekopp, Bartholdt, Beier, Liebert, 2007; Lutchmaya et al., 2004; Manning, Kilduff, Cook, Crewther, Fink, 2014). The digit ratio formula, once developed in the prenatal period, stays unchanged throughout the internal uterine development stage and in further periods of life (Brown, Finn, Cooke, Breedlove, 2002a; Garn et al., 1975; Manning, 2002a).

Research has shown that a high concentration of testosterone, manifesting a lower digit ratio, produces greater strength, power and dexterity (Fink, Thanzami, Seydel, Manning, 2006; Hönekopp, Schuster, 2010; Longman, Stock, Wells, 2011). Additionally, it increases the tendency of aggressive behaviour, risk taking, and the willingness to fight (Austin, Manning, McInroy, Mathews, 2002; Bailey, Hurd, 2005; Kociuba, Koziel, Chakraborty, Ignasiak, 2017). Some authors have indicated that not practising any sport correlates with a higher digit ratio compared sporting individual (Bennett, Manning, Cook, Kilduff, 2010; Giffin, Kennedy, Jones, Barber, 2012; Hsu et al., 2015; Manning, 2002b). Furthermore, the competitors with a more masculine digit ratio are better at sports than those with a more feminine digit ratio value (Bennett et al., 2010; Frick, Hull, Manning 2016; Manning, Hill, 2009; Tamiya, Lee, Ohtake, 2012). Recent years have seen increased interest in the importance and possibility of using the digit ratio in determining aspects of human health, physical and behavioural features. Relationships between the digit ratio and the waist-hip ratio (WHR), and the waist-chest ratio (WCR) have been found. (Fink, Neave, Manning, 2003). Also, a negative correlation between the digit ratio and both sports results and motor fitness was found, with a lower digit ratio being mostly predominant in better results and getting higher on the podium than those with a higher digit ratio (Fink et al., 2006; Hone, McCullough, 2012; Hönekopp, Schuster, 2010; Ingham, Whyte, Jones, Nevill, 2002; Longman et al., 2011).

The process of sports selection may consider many aspects: somatic structure, motor fitness and mental predisposition. An early selection in terms of somatic structure shows low effectiveness due to developmental variations in morphological and functional features, as well as genetic conditions of the development rate. At early development stages, it is thus difficult to predict the growth processes. Hence identifying the features that do not change after development and which, at the same time, are related to particular properties of the human organism, seems to be significant for coaches and the sportspeople themselves. Such criteria can be met by the digit ratio, which does not change over ontogeny.

The aim of the paper was to evaluate the digit ratio between groups of women and men, both sporting and non-sporting, and attempt to determine a value typical for sportspeople of both genders; additionally, to evaluate the relations of the digit ratio with both the somatic structure and motor fitness, which could then be used to improve sports selection criteria.

Material and methods

Participants

Ethical approval for the project was obtained from the Ethical Committee at the University School of Physical Education in Wrocław. Their ethical guidelines were followed throughout the study. Participants provided informed oral and written consent prior to testing.

The research material comprised anthropometric measurements together with the results of motor fitness tests of young women ($n = 179$) and men ($n = 404$) practising various sports disciplines. The criterion assumed for selecting the persons for that group was at least a 5-year training experience or having a sports class. The control

group (women $n = 111$, men $n = 82$) were chosen from the students of the Academy of Physical Education, who had declared in the questionnaire survey that they had not undertaken any of the qualified sports nor participated in any regular activities, apart from compulsory activities. The age range of the sample group was 19–25 years.

Measurements and exercise

The height measurements were taken using a GPM Anthropological Instrument measuring body height (B-a), sitting height (B-v), lower limb length (B-tro), and arm span (da3-da3). A spreading calliper from the same manufacturer was also used to measure width measurements of biacromial diameter (a-a), biiliocrystal diameter (ic-ic), knee breadth (cl-cm), and elbow breadth (epl-epm). Measurements were taken using a tape measure of the circumference of the chest, waist, hip, arm at rest and flexed and tensed arm girth. The body mass was measured with electronic scales (accuracy – 0.1 kg). A skinfold calliper (Holtain, UK) with a constant spring pressure of 10 g/mm² was used to measure skinfold thickness (subscapular, triceps, suprailiac and abdominal).

The length of the second (2D) and fourth (4D) digit of both the right and left hands were measured using a Vernier dial caliper (to an accuracy of 0.01 mm) from the pseudo-phalangion (pph) point to the dactylion (da) point. Each measurement was performed 3 times and the average calculated. The results were used to calculate the digit ratio as follows:

$$\text{Digit ratio} = \text{second finger length [mm]} / \text{fourth finger length [mm]}.$$

To estimate the motor fitness of the subjects, four motor fitness tests were used: sit-and-reach, standing long jump, sit-ups, and grip strength of each hand. The tests complied with the Eurofit procedure (1993).

Data analysis

Statistical calculations were performed using Statistica 10.0 (Stat Soft). The distribution of the variables were verified with a Kolmogorov-Smirnov test. In the groups studied, no significant deviations from a normal distribution were found. On this basis, ongoing methods based on a normal distribution were used. The analysis of variance was used to evaluate the intergroup variation and then a Tukey test (RIR) to assess the significance of differences between the pairs of means at a significance level of $p < 0.05$. The level of the connections between the digit ratio and the morphological features and the level of physical fitness were investigated with a Pearson's simple correlation coefficient.

Results

Digit ratio

Analysis of the digit ratio for the right and left hand identified significant differences between the sporting and non-sporting groups of each gender (Table 1). Both sporting women and men showed significantly lower values of the digit ratio as compared with non-sporting control.

Referring the value of that ratio in sporting men to the sporting women, no significant differences in that feature were found. However, a comparison of those men to not-active women demonstrated a considerably higher values of the ratio in women. In turn, non-sporting men showed significantly higher values of the digit ratio than sporting women, and no significant differences with women who are not active physically (Table 1).

Table 1. Statistical characteristics of the digit ratio in the group of sporting and non-sporting men and women

Feature	Training men	Training women	No training men	No training women
2D:4D P	0.973 ^{1,3} ± 0.03	0.974 ^{2,4} ± 0.028	0.993 ^{1,4} ± 0.025	1.003 ^{2,3} ± 0.033
2D:4D L	0.974 ^{1,3} ± 0.029	0.972 ^{2,4} ± 0.026	0.988 ^{1,4} ± 0.027	0.995 ^{2,3} ± 0.025

Significant differences are marked as follows:

1 – differences between SM and NSM; 3 – differences between SM and NSW; 2 – differences between SW and NSW; 4 – differences between SW and NSM.

Anthropological features

Analysing the other anthropometric measurements, most features showed no significant variation between the sporting and the non-sporting people in each gender.

It was noted only that the width of the shoulders and the knee was significantly greater in the sporting women than in the non-sporting ones (Table 2). It was also noted that a slightly greater humerus massiveness was found in the sporting compared to the non-sporting people.

The men in the study also had significantly higher values of all examined features than the women in the study.

Table 2. Statistical characteristics of the anthropological features in the groups of sporting and non-sporting men and women

Feature	Training men	Training women	No training men	No training women
Body mass [kg]	77.05 ± 9.03 ^{3,4}	61.19 ± 8.32 ^{3,5}	76.09 ± 9.89 ^{5,6}	59.25 ± 8.03 ^{4,6}
Body height [cm]	180.86 ± 6.46 ^{3,4}	167.37 ± 5.91 ^{3,5}	178.89 ± 7.03 ^{5,6}	165.65 ± 6.31 ^{4,6}
Lower limb length [cm]	93.36 ± 4.59 ^{3,4}	87.58 ± 4.34 ^{3,5}	91.79 ± 5.21 ^{5,6}	86.51 ± 5.02 ^{4,6}
Sitting height [cm]	95.09 ± 3.27 ^{3,4}	88.98 ± 3.18 ^{3,5}	93.88 ± 3.76 ^{5,6}	88.36 ± 2.82 ^{4,6}
Arm span [cm]	182.28 ± 7.84 ^{3,4}	166.14 ± 6.72 ^{3,5}	180.72 ± 7.86 ^{5,6}	164.46 ± 7.37 ^{4,6}
Biacromial diameter [cm]	41.46 ± 2.27 ^{3,4}	37.24 ± 1.89 ^{3,5}	40.97 ± 2.53 ^{5,6}	36.42 ± 1.93 ^{4,6}
Biliocrystal diameter [cm]	28.58 ± 1.85 ^{3,4}	27.66 ± 1.69 ^{3,5}	28.29 ± 1.79 ^{5,6}	27.50 ± 1.89 ^{4,6}
Elbow breath [cm]	7.05 ± 0.26 ^{3,4}	6.27 ± 0.40 ^{3,5}	7.00 ± 0.27 ^{5,6}	6.18 ± 0.24 ^{4,6}
Knee breath [cm]	9.87 ± 0.56 ^{3,4}	9.36 ± 0.64 ^{3,5}	9.75 ± 0.53 ^{5,6}	9.01 ± 0.53 ^{4,6}
Chest circumference [cm]	88.85 ± 5.68 ^{3,4}	77.28 ± 6.26 ^{3,5}	88.54 ± 6.60 ^{5,6}	77.00 ± 6.54 ^{4,6}
Waist circumference [cm]	81.09 ± 6.19 ^{3,4}	71.03 ± 6.35 ^{3,5}	80.50 ± 7.37 ^{5,6}	71.06 ± 7.19 ^{4,6}
Arm at rest circumference [cm]	30.37 ± 2.71 ^{3,4}	26.55 ± 2.56 ^{3,5}	30.69 ± 3.06 ^{5,6}	26.18 ± 2.49 ^{4,6}
Flexed and tensed arm circumference [cm]	34.08 ± 2.92 ^{3,4}	28.58 ± 2.65 ^{3,5}	34.20 ± 3.38 ^{5,6}	27.89 ± 2.41 ^{4,6}
Hip circumference [cm]	98.85 ± 5.33 ^{3,4}	97.11 ± 6.22 ^{3,5}	98.77 ± 6.18 ^{5,6}	96.22 ± 5.77 ^{4,6}
Subscapular skinfold [mm]	10.03 ± 2.92 ^{3,4}	12.06 ± 4.33 ^{3,5}	10.17 ± 3.50 ^{5,6}	11.54 ± 3.78 ^{4,6}
Triceps skinfold [mm]	6.61 ± 2.82 ^{3,4}	11.07 ± 3.31 ^{3,5}	6.40 ± 2.76 ^{5,6}	10.60 ± 3.31 ^{4,6}
Suprailiac skinfold [mm]	10.55 ± 5.59 ^{3,4}	14.42 ± 5.82 ^{3,5}	11.00 ± 5.83 ^{5,6}	15.90 ± 5.93 ^{4,6}
Abdominal skinfold [mm]	12.23 ± 5.77 ^{3,4}	15.69 ± 5.02 ^{3,5}	12.72 ± 6.92 ^{5,6}	16.18 ± 5.31 ^{4,6}

Significant differences are marked as follows:

1 – differences between SM and NSM; 4 – differences between SM and NSW; 2 – differences between SW and NSW; 5 – differences between NSM and SW; 3 – differences between SM and SW; 6 – differences between NSM and NSW.

Motor fitness

The only important differences in motor fitness were found for the sit-up test for the women, where those practising sports scored higher than the non-sporting women (Table 3). Analysis of the standing long jump did not show any significant differences; however, some tendencies to better results were noticed for the active persons in comparison to the non-active, both men and women.

The men from both groups had significantly higher values of all motor fitness tests than the women under the study, apart from sit-and-reach. Here, significantly better results were achieved by the sporting women. The results of the non-active women were similar to the men's results.

Table 3. Statistical characteristics of motor fitness in the groups of sporting and non-sporting men and women

Feature	Training men	Training women	No training men	No training women
Right hand grip strength [kg]	47.28 ±7.71 ³⁴	30.78 ±7.36 ³⁵	47.20 ±7.99 ⁵⁶	28.95 ±6.24 ⁴⁶
Left hand grip strength [kg]	44.65 ±7.77 ³⁴	28.24 ±4.43 ³⁵	45.20 ±7.92 ⁵⁶	26.71 ±4.34 ⁴⁶
Sit-ups	27.55 ±4.26 ³⁴	22.92 ±4.86 ²³⁵	26.93 ±4.96 ⁵⁶	21.35 ±4.48 ²⁴⁶
Standing long jump [cm]	2.23 ±0.23 ³⁴	1.70 ±0.24 ³⁵	2.17 ±0.25 ⁵⁶	1.63 ±0.23 ⁴⁶
Sit-and-reach [cm]	25.10 ±8.04 ³	28.23 ±8.74 ³⁵	24.63 ±8.08 ⁵	27.72 ±8.40

Significant differences are marked as follows:

1 – differences between SM and NSM; 4 – differences between SM and NSW; 2 – differences between SW and NSW; 5 – differences between NSM and SW; 3 – differences between SM and SW; 6 – differences between NSM and NSW.

Correlations of the digit ratio with somatic features and motor fitness test results

For the women as a whole, in evaluating the correlations of the digit ratio with the somatic structure and the results of motor fitness tests, there were only low values of correlation coefficients. Otherwise, significant relations were found (Table 4).

Table 4. Correlation of the digit ratio in the right and left hand with features of the somatic structure and motor tests in the group of women

Feature	2D:4DR	2D:4DL	Feature	2D:4DR	2D:4DL
Body mass	0.00	0.01	Flexed and tensed arm circumference	0.06	0.04
Body height	-0.10	-0.12	Hip circumference	0.04	0.09
Lower limb length	-0.08	-0.11	Subscapular skinfold	0.07	0.09
Sitting height	-0.10	-0.09	Triceps skinfold	0.06	0.12
Arm span	-0.13	-0.14	Suprailiac skinfold	0.09	0.10
Biacromial diameter	-0.11	-0.08	Abdominal skinfold	0.05	0.09
Biiliocrystal diameter	-0.05	-0.02	Right hand grip strength	-0.10	-0.14
Elbow breath	-0.08	0.02	Left hand grip strength	-0.12	-0.15
Knee breath	-0.07	0.03	Sit-ups	-0.07	-0.06
Chest circumference	0.07	0.05	Standing long jump	-0.14	-0.09
Waist circumference	0.10	0.09	Sit-and-reach	-0.03	-0.06
Arm at rest circumference	0.07	0.07			

Important negative dependencies were observed between the arm span and digit ratio for both hands. It means that the more masculine was the structure of the 2D:4D fingers, the greater the span of the upper limbs. The digit ratio of the left hand was negatively significantly related to body height and the length of the upper limb, while the arm skinfold was positively significantly related.

The correlation of the digit ratio with the results of the motor tests in women are poor. Significant negative dependencies were noted only between the digit ratio and the handgrip strength and standing long jump.

In the whole group of men, as in the group of women, there are poor correlations between the digit ratio with the somatic structure and physical fitness tests (Table 5). As for the somatic features, a significant dependence between the digit ratio of the right hand with the sitting height was found. For the motor tests, a significant negative dependence was noted between the digit ratio of the right hand with handgrip strength. The digit ratio of the left hand was significantly correlated with the standing long jump.

Table 5. Correlation of the digit ratio in the right and left hands with features of the somatic structure and motor tests in the group of men

Feature	2D:4DR	2D:4DL	Feature	2D:4DR	2D:4DL
Body mass	-0.03	0.04	Flexed and tensed arm circumference	-0.03	0.04
Body height	-0.08	-0.02	Hip circumference	0.02	0.08
Lower limb length	-0.08	-0.02	Subscapular skinfold	0.00	0.03
Sitting height	-0.11	-0.05	Triceps skinfold	0.05	0.02
Arm span	-0.06	-0.03	Suprailiac skinfold	-0.02	0.02
Biacromial diameter	-0.02	0.00	Abdominal skinfold	0.01	0.01
Biiliocrystal diameter	-0.01	0.00	Right hand grip strength	-0.10	-0.02
Elbow breadth	0.01	0.02	Left hand grip strength	-0.09	-0.04
Knee breadth	-0.05	0.04	Sit-ups	0.03	-0.03
Chest circumference	0.00	0.08	Standing long jump	-0.07	-0.10
Waist circumference	-0.01	0.04	Sit-and-reach	0.01	0.03
Arm at rest circumference	-0.02	0.06			

Discussion

The results of this research showed that the mean values of the digit ratio in the men were typical for males. The representatives of the sporting group did show significantly lower values of digit ratio than the non-sporting men: 0.9733R vs 0.9736L. The non-sporting men had values of 0.9931R and 0.9875L. Similarly, in the women; the mean values of the digit ratio in the sporting group were significantly lower than in the non-sporting group. In the right hand, the sporting women averaged 0.9735, and in the left hand 0.9722. In the group of non-sporting women, the digit ratio values were 1.0025R and 0.9945L, respectively.

Own results agree with those reported by other authors. N.A. Giffin et al. (2012) found the digit ratio in a group of competitors averaged 0.97 in the men and 0.98 in the women, while the non-sporting group recorded a significantly higher digit ratio (men: 0.99, women: 1.00). A comparative analysis for skiers of both sexes presented by J.T. Manning (2002b), as well as by M. Bennett et al. (2010) in rugby players, also showed significantly lower digit ratios compared to the control (non-sporting) group. It suggests that those with a more masculine digit ratio are predisposed to sports. Both women and men with a lower value of digit ratio represent, in general, a higher

sporting level. One can thus assume that a high exposure to prenatal testosterone, seen in the lower values of the digit ratio, coincided with the tendency to taking up physical activity in childhood, which, in turn, enhanced the sports skills and motor fitness, as well as a motivation for physical competition in various disciplines (Giffin et al., 2012; Koziel et al., 2017). The dimorphic nature of the features studied matches many earlier reports on males showing lower values of digit ratio than in women (Manning et al., 1998; McFadden, Westhafer, Pasanen, Carlson, Tucker, 2005; Mularczyk, Ziętek-Czeszak, Ziętek, 2014; Okten, Kalyoncu, Yaris 2002). Our own results showed this difference between the sporting men and non-sporting women. Sportsmen showed significantly lower values of digit ratio than did the female representatives of the control group. However, the sporting women did not differ considerably in terms of the mean value of the digit ratio from the sporting men. No definite dimorphism in digit ratio in the professional sportsmen, and significantly lower mean values of digit ratio in sportswomen compared with non-sporting men, were also shown by N.A. Giffin et al. (2012), C.C. Hsu et al. (2015) and by M. Kociuba, S. Koziel and R. Chakraborty (2016). It can thus be assumed that women with a more masculine digit ratio are better predisposed to various sports disciplines and better sport results.

Referring to the control groups, no considerable gender differences were found. However, the subjects showed a gender-typical tendency; in non-sporting men the second finger was shorter than the fourth one, whereas in the women it was the opposite (a digit ratio above 1).

Interestingly, a digit ratio of 1 or above occurred in some men both from the sporting and non-sporting groups. However, in the sporting groups that frequency was definitely lower than in the control groups. N.A. Giffin et al. (2012) found that in the sporting men a ratio below 0.98 was more frequent with 68% of the subjects of that group, while just 28% in the non-sporting persons, and in the sporting women, the digit ratio 0.98 was recorded in 44% of the subjects, but only 14% in the control group. Similar results were noted by D.M. Moffit and C.B. Swanik (2011), as well as by J.T. Manning (2002a) who observed in professional football players that in as many as 90% of them the digit ratio was below 0.98. In the control group, only half of the individuals were so low.

The results of this study are similar to the results provided above. In the sporting men, a digit ratio of 0.98 or below occurred in almost 71% of the subjects, and in 75.5% of the sporting women. Among the sportspeople (both sexes) there were some people with a digit ratio above 0.98, but relatively few; 29% of men and 24.5% of women. A typically feminine ratio (≥ 1) was found in 15.3% of sporting men and 12.2% of sporting women. In the non-sporting groups the percentage of persons with a digit ratio ≤ 0.98 was definitely lower than in the sporting groups, at 47% for men and 30% for women. A typically feminine digit ratio (≥ 1) was found in 38.5% of the men and in as many as 52.2% of the women. In the others the values ranged down to 0.981.

Lower values of the digit ratio are the effect of a high exposure to testosterone in the uterus. A study focusing on the biological grounds for this behaviour has identified the effects of the prenatal impact of testosterone on other adult psycho-physiological parameters (Neave, Laing, Fink, Manning, 2003). It suggests that a high level of testosterone in the prenatal period can have a constant masculinising effect on human behaviours (Manning, 2002a). One can thus assume that testosterone in the prenatal period has a stronger effect on physical aggression than does the level of testosterone in adults, which can potentially account for the dependence between the sports efficiency and the digit ratio (Hönekopp, Manning, Müller, 2006). Such a conclusion is partially based on the assumption that the digit ratio reflects the organisational effect of androgens on brain functions (Bailey, Hurd, 2005; Percivalle et al., 2013).

The objective of the further analyses in our study was to evaluate differences in the somatic body structure and motor fitness in the sporting and non-sporting groups within each sex. Following the earlier studies, one should assume that they would be significant. However, this study has not identified a clear variation in the basic somatic features or in motor fitness in sporting and non-sporting people. It can be assumed that the relatively poor differences between the representatives of the two groups within a given sex are due to the fact that the study group included representatives of various sports disciplines, e.g. team games, athletics, swimming, combat sports, which are specific in terms of various aspects of somatic structure (varied length and width, body muscles). However the control group was made up of the students of University of Physical Education, which can suggest that students of such universities are morphologically better predisposed to practise various forms of physical activity and, in general, are more willing to take up a recreational physical activity, thus showing also a greater care of their figure by adequate nutrition. Additionally, the study syllabus forces them to a greater than average physical effort.

The correlations of the digit ratio were low with features of the somatic structure and the results of motor tests. However, women showed negative correlations of the ratio with almost all the features describing the skeleton, in terms of its length and massiveness. It means that the higher the digit ratio, the lower the length and width measurements, which is typical for the anatomy of the feminine body and accounts for such dependencies. Positive correlations of the digit ratio with skinfolds well reflect the specificity of a greater fat content in women.

The digit ratio in the group of women also showed mostly low correlations with the results of motor tests. Significant dependencies were noted, however, between the digit ratio in the right hand and the long jump length and the handgrip strength. The lower the ratio, the better the test results. Such direction of the correlations was also observed by H. Lu et al. (2017). The tests cover strength and time-trial, where a high muscle content is significant (a feature not characteristic for women). A more feminine body composition is connected to relatively higher share of the fat tissue in the body mass and a lower share of muscle.

Referring to the correlations in the male group, as in the female group, a poor relation of the digit ratio with the features of the body structure was observed. A negative correlation coefficient points to increases in all the body measurements with a decrease in the digit ratio. As for motor fitness tests, there was a considerable negative correlation of the digit ratio of the right hand with handgrip strength of both hands. Similar results are reported by other authors (Fink et al., 2006; Zhao, Li, Yu, Zheng, 2012), who found the occurrence of negative significant correlations between the digit ratio for the right hand with handgrip strength. Our own analysis found significant correlations with the long jump. It must be due to the fact that the more masculine body composition (more muscle content, lower fat content, and longer limbs) helped in strength and speed tests (Zatsiorsky, Kraemer 2006).

With our own results and the reports of other authors, it can be stated that the digit ratio can be an additional element defining a predisposition to sports activity in both sexes. Due to the unchanging value of the digit ratio over lifetime, this feature seems especially useful in the selection of young people for professional sports. It is most important at a preliminary selection made during the period of progressive development, where morphological variables undergo dynamic changes and sometimes it is difficult to predict their final effect. It seems, however, that the digit ratio does not allow to make a definite selection of a person for a specific sports discipline due to the low correlation of the ratio with feature of the somatic structure and the level of motor fitness. It is also confirmed by similar reports of other authors (Manning et al., 2000; Manning, 2002a; Muller et al., 2012). The ambiguous results presented in literature are probably due to research being performed in various ethnic groups residing in

various latitudes (Danborn, Adebisi, Adelaiye, Ojo, 2008; Fink et al., 2003; Kalichman, Batsevich, Kobylansky, 2017; Krakowiak, Čabrić, Sokolowska, 2013).

Conclusions

This study showed significant differences in the digit ratio between sporting and non-sporting persons, both in men and in women. Men and women from sporting groups showed definitely lower values of the digit ratio than did those from non-sporting groups. Sportswomen showed a typically masculine digit ratio, the mean values of which were significantly lower than the mean values in non-sporting men. Non-sporting women showed higher values of the digit ratio in both hands, and just the right hand presented a typically feminine digit ratio (≥ 1). The correlations between the digit ratio and features of the body structure were low. We found significant negative correlations between the digit ratio and sitting height in the whole group of men. In the women we noticed a significant negative correlation of digit length with arm span and body height, as well as a positive correlation with arm skinfold. As for motor tests in both sexes, significant negative correlations between the digit ratio and handgrip strength as well as with the long jump length were recorded. The formula of finger lengths can be an additional element determining the predisposition to engage in sports activities in both sexes.

Disclosure of interest

The authors declare that they have no competing interests.

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INFLUENCE OF KEY-POINTS OF RING MUSCLE-UP EXECUTION ON MOVEMENT PERFORMANCE: A DESCRIPTIVE ANALYSIS

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Abstract Background: The inclusion of gymnastic-based movements in workout routines in many exercise training programs, generally called mixed modality training (MMT), and even in many competitions, is increasingly common. In contrast to artistic gymnastic competitions, MMT workouts aim to complete as many movements as quickly as possible, which tends to deform the movement pattern proposed by artistic gymnastics. Execution of the MMT workouts with more of the gymnastics-based style (i.e., based on the gymnastics movement pattern) could improve performance in exercises with a high-level complexity, such as the “ring muscle up” (RMU). Thus, this study aimed to analyze the kinematic aspects of RMU, performed by a former gymnast both with and without the gymnastics based style.

Methods: A former gymnast with a successful transition to MMT, carried out RMU using two movement patterns: 1) close to the classical artistic gymnastics pattern (“Front uprise”), and 2) close to that used by many athletes not from gymnastics. The athlete performed RMU, three times with each proposed movement pattern. Images were captured using a high-speed digital camera. Hip and ankle displacement, velocity and acceleration were recorded and analyzed.

Results: The execution of RMU was faster and the hip vertical displacement was greater when RMU was carried out with a gymnastics-based style, while ankle displacement path, peak velocity and acceleration were lower.

Conclusion: The use of a gymnastics-based style to carry out RMU seems to be advantageous from the biomechanical point of view, favoring the performance of RMU.

Key words movement economy, artistic gymnastics, crossfit, Mixed Modality Training, kinematics

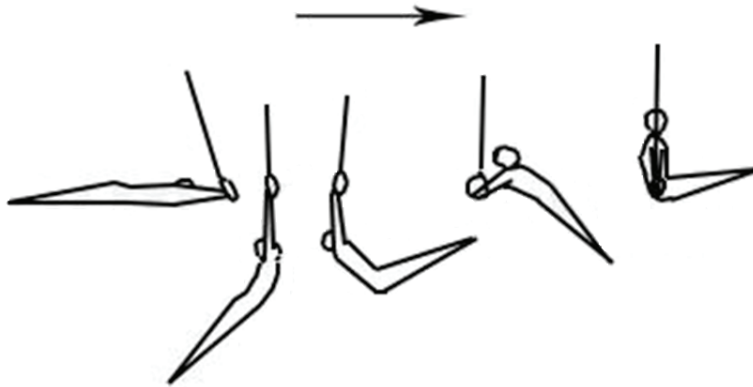
Introduction

Many trademarked exercise training programs (e.g. CrossFit, Insanity, Gym Jones, etc.) use high intensity workouts of mixed modalities, such as aerobic exercises, artistic gymnastics based movements, and weightlifting based exercises, aiming at boosting condition and strength training. As such, these exercise programs are recognized as Extreme conditioning programs (Bergeron et al., 2011), high-intensity functional training (Bechke, Kliszczewicz, Feito, Kelemen, Nickerson, 2017) and mixed modality training (MMT) (Marchini, Pereira, Pedroso, Christou, Neto, 2017; Figueiredo, Pereira, Neto, 2018).

Wide scientific knowledge exists regarding exercises such as runs, jumps, single or double under, and Weightlifting-based exercises in both physiologic and biomechanical aspects (Martin, Morgan, 1992; Comfort, Allen, Graham-Smith, 2011; DeWeese, Serrano, Scruggs, Sams, 2012), while gymnastic-based movements, despite their high-level complexity, have not been widely studied. Regularly, sport coaches have been adapting artistic gymnastics exercises, such as the “ring muscle-ups”, for us in general conditioning. In fact, there is a duality between artistic gymnastics and gymnastic based movements applied in MMT workouts, where the first is focused on the quality of movement, which includes symmetry and a perfect posture at each step of the movement, while the second is focused on intensity, carrying out as many movements as possible and/or in a little time as possible, according to the workout design (e.g. AMRAP workout: as many rounds/repetitions as possible, or “for time” workout). It is evident then that the biomechanical aspects tend to be modified/adapted from the classical artistic gymnastics when used in MMT workouts.

The increased popularity of the MMT methodology is notorious, owing to promising performance results and the motivational aspects (Claudino et al., 2018). However, some workouts requiring gymnastic skills have been associated with many movement adaptations which may result in both limited performance and the increased risk of injury (Meeusen, Borms, 1992). The exercise named “ring muscle up” (RMU) is an adaptation from the movement named “Front uprise” in artistic gymnastics, and is presented in Figure 1. Briefly, after swinging like a pendulum, the front uprise movement begin at the arch position, followed by a descending phase with the body fully extended/aligned (i.e. ankle at dorsiflexion, knee and hip extended), transiting to a forward/upward displacement with a hollow position, followed by a powerful hip extension, synchronized to a powerful pull of the rings towards the shoulders synchronized to a powerful pull of the rings at the shoulders plane (i.e. glenohumeral extension/adduction and internal rotation, with the elbow extended along the movement, combined to a scapular protraction), boosting the hip upward, while the upper body is “inverted” (i.e. displaced from a horizontal position to a vertical position, while the hip is maintained extended). The movement is finished with a hip backward displacement, until the hip reaches the plane of the rings, where the gymnast adopts the L-sit position (i.e. arms along the trunk with the body weight supported by the hands gripping the rings, hip flexion with knee extension and ankle plantar flexion).

The execution of this movement requires a high degree of motor control to keep the upper and lower body extremities “connected” to the core, i.e. the muscles need to be active along all of the movement to maintain an adequate alignment of each segment, optimizing the energy transfer between the fixed extremity (i.e. hands gripping the rings) and the free extremity (i.e. the feet). Then, from a narrow viewpoint, these mechanical aspects are essential to achieve an efficient movement, in other words, carry out the task with a minor energy demand.



Note: After swing as a pendulum, front uprise movement begin at the arch position (left/first model), followed by a descending phase with the body fully extended/aligned (i.e. ankle at dorsiflexion, knee and hip extended, as exposed in the second model), transiting to a forward/upward displacement with a hollow position (third model), followed by an powerful hip extension, synchronized to a powerful pull of the rings towards the shoulders synchronized to a powerful pull of the rings at the shoulders plan (i.e. glenohumeral extension/adduction and internal rotation, with the elbow extended along the movement, combined to a scapular protraction), boosting the hip upward, while the upper body is "inverted" (i.e. displaced from a horizontal position to a vertical position, while the hip is maintained extended, as exposed in the fourth model). The movement is finished with a hip backward displacement, up to hip reach the ring's plan, when the gymnast adopt the L-sit position (i.e. arms along the trunk with the body weight supported at hands gripped to the rings, hip flexion with knee extension and ankle plantar flexion, as exposed in the right/last model).

Figure 1. Scheme of Front uprise movement

Source: <http://www.gymdrills4profs.com/gymnastics-events/skill-drills-still-rings/gymnastics-still-rings-front-uprise.html>.

Curiously, regularly, it is possible to observe enthusiasts and athletes of MMT carrying out RMU with a different motor pattern from the "front uprise" exercise described above, which is evident in videos on social media and from events including MMT professional athletes (e.g. CrossFit Games, National Pro Grid League [NPGL-GRID] and others). A detailed analysis shows three main movement adaptations: 1) it is common to observe athletes bending the knees at the arch position, braking the body alignment at the start position, a clear sign of "connection loss" between the core and the extremities; 2) it is common to observe athletes pulling the rings to the chest, to the lower ribs, or to the hips at the "pull phase" (fourth model in Figure 1) and bending the hips and knees, which approximates the head to the knees, aiming to rotate the upper body and fit to the rings, rather than carry out an "inversion" as described for the fourth model in figure 1; 3) it is common to observe athletes needing to carry out a powerful elbow extension after the hips reach the rings plane, because they did not fit to the rings with the elbow already extended, then, they need to complete the movement, since according to the MMT movement convention and rules of competitions with the MMT design, this is a criteria to consider the movement completed (i.e. to count the repetition as valid).

All the described adaptations do not impede completion of the task, but from a kinematics point of view, it does not guarantee efficient movement, as represented by a quick movement with the least energy cost. Thus, this study aimed to analyze the kinematic aspects of RMU, performed by a former gymnast both with and without the gymnastics based style.

Materials and Methods

A Brazilian former gymnast (male; 26 years old; height: 167 cm; weight: 80 kg; 17 years of experience in artistic gymnastics, with 12 years (2001–2013) dedicated to artistic gymnastic competitions) who had a successful transition from artistic gymnastics to MMT, as confirmed by a notable performance in the main Brazilian MMT competitions, especially in workouts involving gymnastics movements such as RMU, was invited to perform RMU using two movement patterns: 1) close to classical artistic gymnastics (i.e. close to the movement pattern used in “Front uprise”); and 2) close to that used by many athletes not from gymnastics. The former gymnast exhaustively watched many videos on the adapted movement pattern as commonly used by many athletes not from gymnastics. This adapted movement pattern diverged from the classical gymnastic pattern in the three key points described previously.

All the procedures were conducted in conformity with the Helsinki Declaration and the study was approved by the local Human Research Ethics Committee (protocol #3.425.388). Written informed consent was obtained from the volunteer gymnast.

The gymnast was asked to analyze the movement patterns and reproduce them with the greatest possible precision. After analyzing the videos and practicing for a long time, six RMU performances were carried out, three times with each proposed movement pattern. Images of these movements were captured at 240 frames/sec using a high-speed GoPro® Hero 5 Black (GoPro Inc., USA) digital camera positioned 8 meters from the rings to record the movement in the sagittal plane parallel to the direction of body displacement. Selected surface anatomical reference points were marked with white tape; at the hip (greater trochanter), lateral malleolus and wrist. The tracking of hip and ankle reference points were analyzed using Kinovea® v0.8.26 software (www.kinovea.org) to produce the follow Kinematic parameters: hip and ankle displacement (total path and mean vertical displacement), velocity and acceleration during each RMU attempt. For kinematic analysis, the start position was defined as the arch position identified as the higher position before starting the downward displacement, and the end position was established as the moment when the hip reaches the ring plane and the body was aligned to the rings. These variables were obtained from each of the three attempts of each execution pattern, and the data presented as mean \pm standard deviation. The reference point attached to the wrist was used to indicate the distance between the wrist and hip when the hip reached the ring plane.

Results

Figure 2 shows the sequence of movements from an attempt of RMU in each style (i.e., Gymnastics based and MMT based).

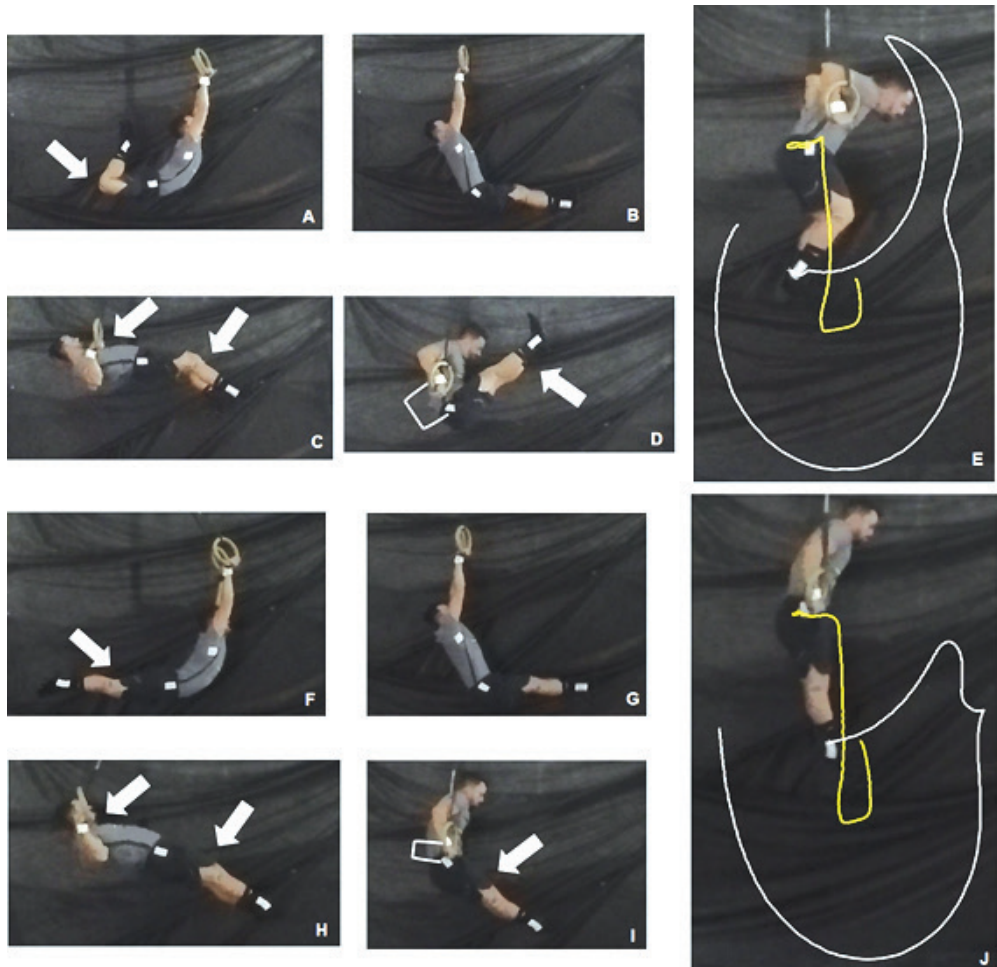
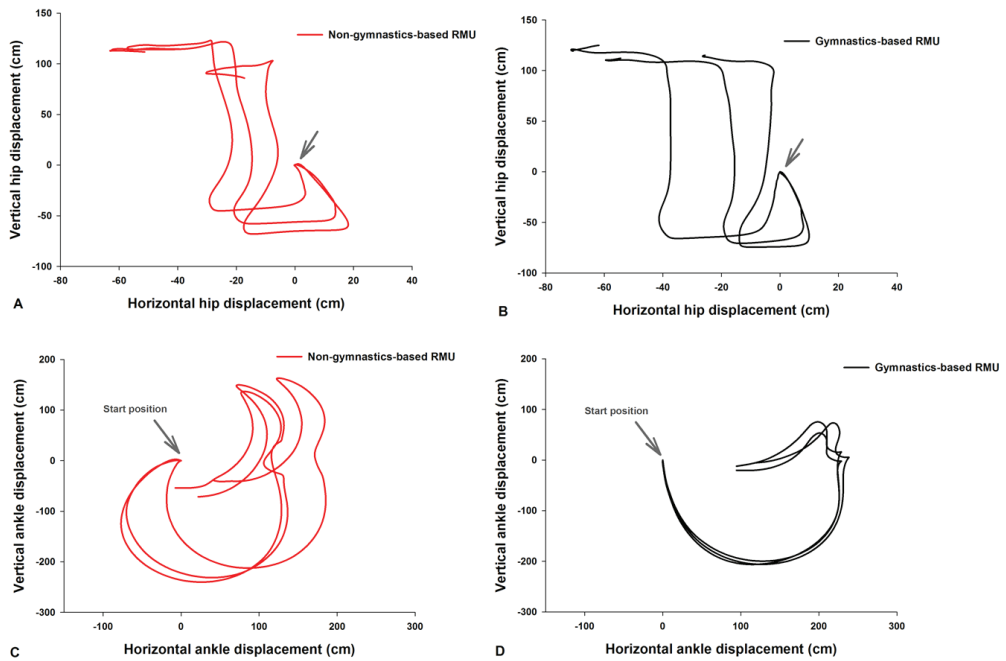


Figure 2. The sequence of movements from an attempt of RMU with each style: Non-gymnastics-based (A–E), and Gymnastics-based (F–J)

Figure 3 shows the vertical and horizontal displacements (i.e. path) of the hip and ankle during the RMU carried out with the Gymnastics style and without. It is possible to observe a distinct displacement pattern from each movement style, especially at ankle tracking.



Note: The scales were adjusted to be equal for vertical and horizontal displacement at each movement style.

Figure 3. Vertical and horizontal displacement of hip (A and B) and ankle (C and D) during three attempts of RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

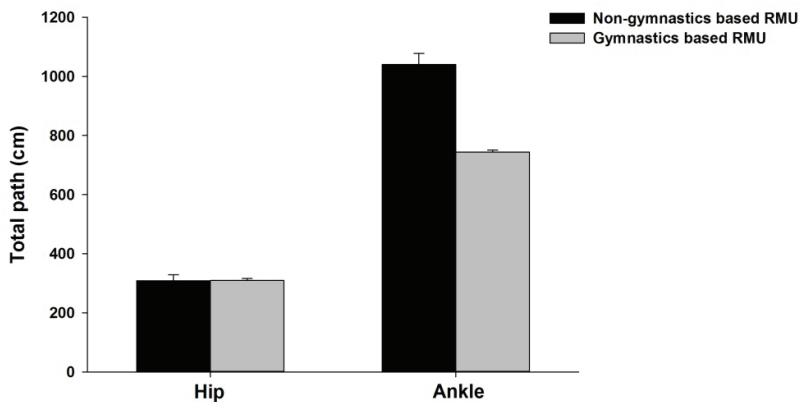


Figure 4. Mean total path of hip and ankle during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

Tracking of the hip and ankle during the movement exhibits a similar hip path displacement of (Non-Gymnastics-based: 308.8 ± 19.7 ; Gymnastics-based: 309.2 ± 6.9 cm), and a greater ankle path displacement without a Gymnastics-based style (Non-Gymnastics-based: 1040.1 ± 37.4 ; Gymnastics-based: 744.0 ± 6.6 cm) (see Figure 4). When analyzing the amplitude of vertical hip displacement, the gymnastics-based RMU exhibited a greater performance, since the amplitude was on average 14.7 cm greater, indicating that the hip reach a higher altitude, which facilitates the fit to the rings.

The mean time to complete the RMU was on average 268.7 milliseconds (ms) quicker when performed with a gymnastics based style, indicating that this style promotes a faster way to reach the final position, as is shown in the x-axis of Figure 5. Curiously, the peak velocity achieved with non-gymnastics-based style was on average greater for the hip (Non-Gymnastics-based: 7.1 ± 0.6 ; Gymnastics-based: 7.0 ± 1.0 m/s) and ankle (Non-Gymnastics-based: 14.1 ± 1.1 ; Gymnastics-based: 13.7 ± 0.4 m/s). The mean velocity was also greater for ankle (Non-Gymnastics-based: 6.6 ± 0.2 m/s; Gymnastics-based: 0.5 ± 0.0 m/s) with the non-gymnastics-based style, however, the hip mean velocity along the RMU was greater with gymnastics-based style (Non-Gymnastics-based: 1.9 ± 0.2 m/s; Gymnastics-based: 2.4 ± 0.1 m/s). Figure 5 exhibits the hip and ankle displacement velocity obtained during the RMU with and without the gymnastics-based style, while Figure 6 shows the respective mean and peak displacement velocities obtained.

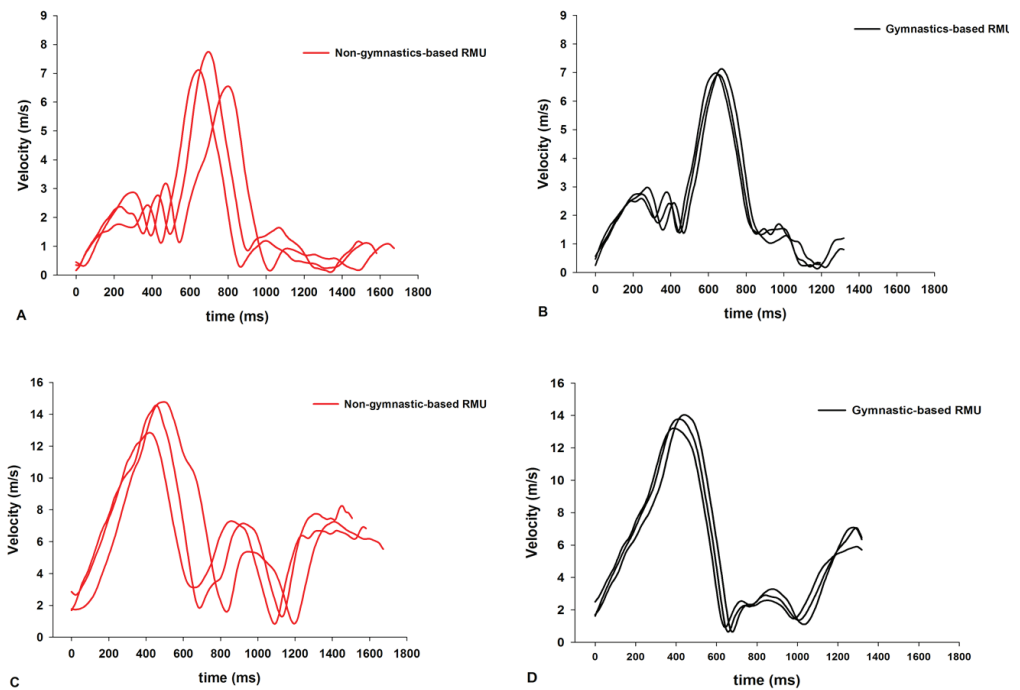


Figure 5. Hip and ankle displacement velocity during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

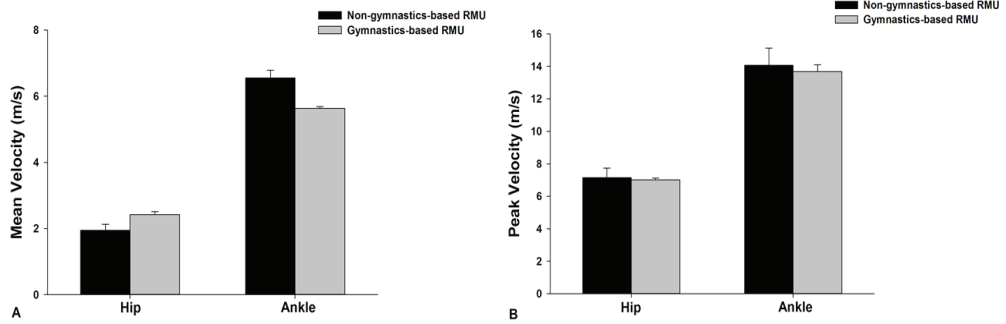


Figure 6. Mean (A) and Peak (B) velocity of hip and ankle during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

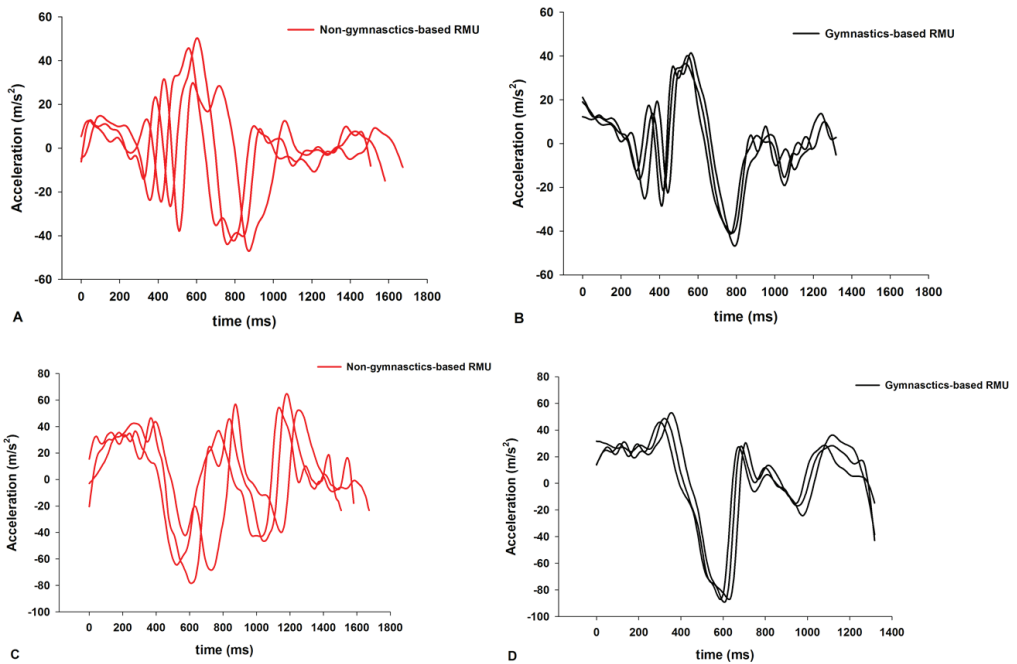


Figure 7. Hip and ankle acceleration during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

The peak acceleration achieved with the non-gymnastics-based style was on average greater for the hip (Non-Gymnastics-based: 42.5 ± 9.7 ; Gymnastics-based: 39.3 ± 2.6 m/s^2) and ankle (Non-Gymnastics-based: 58.6 ± 5.4 ; Gymnastics-based: 49.2 ± 3.6 m/s^2). The mean acceleration was also greater for the ankle (Non-Gymnastics-based: 2.7 ± 0.5 ; Gymnastics-based: 3.1 ± 0.6 m/s^2) with the non-gymnastics-based style; however, the hip mean acceleration along the RMU was greater with gymnastics-based style (Non-Gymnastics-based: 0.3 ± 0.07 ; Gymnastics-based: 0.3 ± 0.3 m/s^2). Figure 7 exhibits the hip and ankle displacement acceleration obtained during the RMU with and without the gymnastics-based style, while Figure 8 shows the respective mean and peak displacement acceleration obtained.

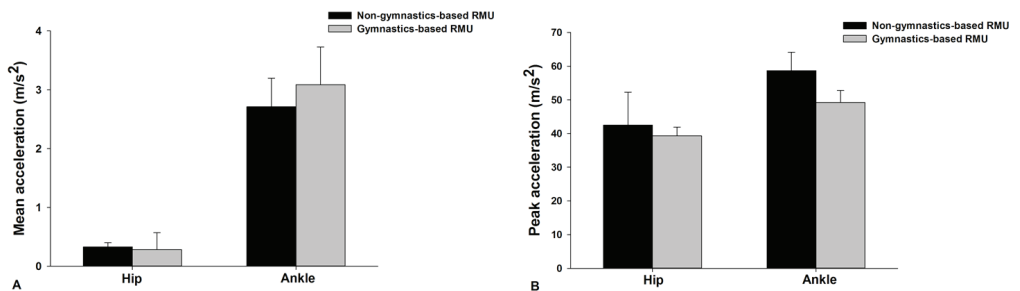


Figure 8. Mean (A) and Peak (B) acceleration of hip and ankle during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

Discussion

This study aimed to analyze the kinematic aspects of RMU carried out by a former gymnast in both a gymnastics-based style and the adapted MMT style. Our results showed that the gymnastics-based style allowed a faster execution with a greater vertical displacement, with a lower effort to reach this performance, as evidenced by the lower hip peak acceleration needed to reach a greater vertical displacement. In addition, the greater ankle path displacement in the non-gymnastics-based RMU evidenced an unnecessary energy demand.

It is known that biomechanical factors play a role in explaining movement economy, which have been studied in tasks such as walking and running (Martin, Morgan, 1992; IJmker, Lamoth, Houdijk, van der Woude, Beek, 2014). K.R. Williams and P.R. Cavanagh (1987) studied the relationship among running mechanics, running economy and performance, suggesting that biomechanical factors may contribute significantly in determining the economy of motion. What was subsequently hypothesized for running could be applied to other motor tasks, such as RMU. In this sense, our results indicate that the execution of RMU with an adequate body alignment between the extremities and core along the entire task, as carried out by gymnasts during many performances on the rings, could lead to a better performance with less energy expended.

For an RMU, the performance could be measured by the elapsed time to complete the task and by the height reached by the hip when crossing the ring's plane. Based on this statement, it is possible to point out that performing a RMU with a gymnastics based style (i.e. close to the movement carried out by a gymnast in "Front uprise") leads to the best performance, which is advantageous when the goal is to carry out as many repetitions as possible in a predetermined time, or a fixed number of RMUs as quickly as possible, both conditions used in many workouts proposed by trademarked exercise training programs.

In this context, the Crossfit Games®, the greatest annual competition with MMT methodology (i.e. where the applied workouts merge weightlifting and gymnastics based tasks) and whose purpose is to crown the fittest man and woman in the world, included in 2018 a task to complete 30 RMU repetitions as quickly as possible (see <https://games.crossfit.com/leaderboard/games/2018?division=1&sort=2&page1>). After observing the performance of the competitors, it is possible to identify that among men, the difference between first and second place was only 6 seconds (1st place: 1'46" [or 106 seconds]; 2nd place: 1'52" [or 112 seconds]), a very low time difference. A movement analysis of these athletes is out of the scope of the present study; however, if we reason from our results where elapsed time to complete a RMU was on average 268.7 ms faster with the gymnastics based style, it would mean that to carry out 30 RMUs, the time saved would reach 8 seconds (0.268 seconds x 30 repetitions = 8.1 seconds). Thus, it may be sufficient time to distinguish first and second place in a high level competition with MMT methodology.

It is important to note that many factors may influence the performance in the cited workout, such as cardiorespiratory capacity, muscle resistance, the number and length of rest periods, and other factors out of the scope of this study. Despite this, it seems clear that the biomechanical factors can influence RMU performance, which could favor a performance during competitive workouts.

Besides the time saved to complete the movement and the higher hip displacement reached with a gymnastics based style, it is worth emphasizing that this performance was achieved with a lower hip peak acceleration, suggesting a lower effort to complete the RMU owing to a better energy transfer along the body segments. Therefore, from the energetics point of view, it is possible to hypothesize that the gymnastics based style could be advantageous, which corroborates the hypothesis of influence of biomechanical factors on the economy of motion (Martin, Morgan, 1992; Ijmker et al., 2014). The influence of the mechanical aspects on the metabolic demands during the RMU should be considered in further studies to confirm or refute our hypothesis.

This study was based on just one athlete, which can be considered a limitation of this study, but the number of former gymnasts with a successful transition from artistic gymnastics to MMT methodology is still small, and gathering these former gymnasts, scattered in many countries, is a hard and complicated task. The present study is not a conclusive analysis, but may pave the way for further studies, gathering these athletes to improve knowledge regarding the use of gymnastics principles in the MMT. Specifically, further studies should compare the mechanical aspects and metabolic demands from non-gymnasts before and after a training period to achieve a gymnastics based RMU pattern.

In conclusion, our results suggests that the use of a gymnastics-based style to carry out a RMU, maintaining an adequate body alignment at the arch position, a hollow position at the ring's plane, associated with a powered pull toward the shoulders as used by gymnasts during "Front uprise", seem to be advantageous from the biomechanical point of view, favoring the performance of RMU, which may be especially useful during exercises with many RMU repetitions.

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Conflicts of Interest

The authors declare no conflict of interest.

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COMPARISON OF SUBJECTIVELY PERCEIVED PRO-HEALTH EFFECTS OF PRACTICING VARIOUS FORMS OF BODY & MIND TRAINING IN WOMEN

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Abstract Background: Body & mind trainings are forms of aerobics, the aim of which, apart from improving physical fitness, is to additionally provide mental relaxation. The aim of this study was a comparison of physical and mental pro-health effects from practicing Hatha yoga, Pilates and bodyART.

Material and methods: Our own self-assessment questionnaire was used assess the impact of selected forms of body & mind training on the physical and mental fitness of people regularly practicing the forms. A group of 81 women practicing Hatha yoga, Pilates or bodyART for a minimum of 2 workouts per week were qualified. Additional inclusion criteria involved at least a 2-month training period and not practicing the other sport disciplines in study period.

Results: After regular body & mind training, significant beneficial changes involving primarily the reduction of joint pain and increased flexibility were subjectively noticed by the participants. Changes included a significant reduction of back pain for Hatha yoga and Pilates and reduction of knee pain and improvement of the sense of balance for bodyART.

Conclusions: Practicing body & mind forms has a beneficial impact on the perception of psychophysical health, regardless of the type of training, while the bodyART form generally showed the greatest number of effects.

Key words pro-health training, body & mind, Hatha yoga, Pilates, bodyART

Introduction

Body & mind trainings are modern forms of aerobic workouts combining physical exercises with mental training, through concentration of attention on breathing and body work. Their goals, apart from improvements in physical fitness, are to provide psychical relaxation and to restore body and mind balance. Body & mind forms can include all types of collective aerobic trainings that are focused on unity of the body and mind, learning correct breathing, and forming a body consciousness. Many types of training meet these criteria, and with the freedom to create new

workout plans with original specific names, their number are increasing. The most popular and recognizable forms of this type are Hatha yoga, Pilates and bodyART (Podciechowska, Karpińska, Sikorska 2015; Figurska, 2018).

Hatha yoga

One of the oldest body & mind forms practiced nowadays is Hatha yoga. The word “hatha” means strong effort and describes the combination of physical exercise, breathing and relaxation techniques to improve general fitness. Yoga constitutes a system of holistic hygienic, educational and therapy in which the essential element is a specific philosophy, while Hatha yoga is focused on body training, without the requirement of any spiritual or metaphysical principle (Podciechowska et al., 2015; Palica, Zwierzchowska, 2012; Grabara, 2009; Sorosky, Stilp, Akuthota, 2008).

The practice of Hatha yoga consists of special positions (*asanas*) which in a controlled way stretch and strengthen the muscles and stimulate a sense of balance (Figure 1a, 1b). *Asanas* include lying, sitting, standing, as well as inverted positions such as headstands. Each *asana* position is held for long time before moving to the next *asana*. The word “*asana*” literally means “comfortable position”, thus the main goal of practitioners is to stay effortlessly and comfortably in each position. To increase the effectiveness, the *asanas* are complemented with special breathing exercises called *pranayamas*. These techniques are not intended to increase the ventilation, but rather to set correct proportions between the phases of breathing (Podciechowska et al., 2015; Palica, Zwierzchowska, 2012; Grabara, 2009; Sorosky et al., 2008).

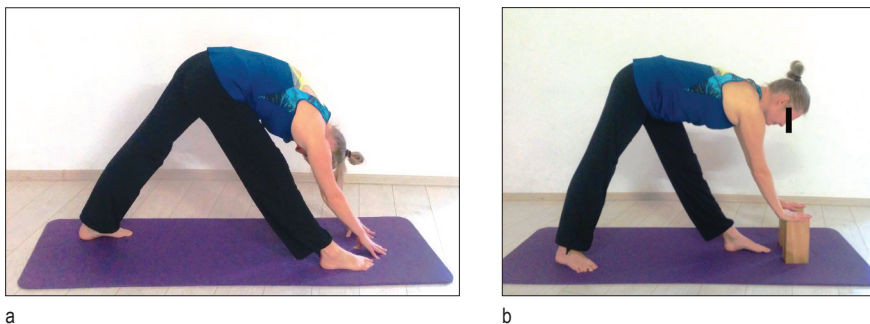


Figure 1. Parsvottanasana – pyramid position: unsupported (a) and with supports (b)

The regular practice of Hatha yoga leads to increase in the range of motion in the joints and helps form a correct body posture and body consciousness, and due to the positive effect on the psyche it improves concentration, tenacity and patience. Particular rotational positions positively improve the work of the digestive system. Application of the breathing techniques assists in tissues oxygenation, increases the metabolism and facilitates toxin removal (Podciechowska et al., 2015; Grabara, 2009; Grabara, Szopa, 2011).

With regard to its pro-health character and the possibility of individual training adjustment, Hatha yoga can be practiced by persons of all ages and fitness levels. Its universality is also emphasized by the fact that it doesn't require any special equipment. Exercises are performed barefooted in loose clothes on non-slip gym mats. There

are not many contra-indications for Hatha yoga and they are non-specific, thus in the case of their occurrence, it is usually possible to avoid a selected group of asanas without having to give up all training (Grabara, 2009).

Pilates

The exercise system was created by Joseph Pilates in the early 20th century and was inspired by Yoga, martial arts and other ancient methods of exercise. During the First World War it was used with hospital patients, and later was adapted for dancers following injuries, and to support their training, and for a long time it was a method reserved exclusively for this group (Sorosky et al., 2008; Kloubec, 2010; Mazur, Marczewski, 2011).

Pilates training is based on simple exercises with a small load matched individually and regularly increased. Its level of exercise is raised not by multiplying the number of exercises, as in the case of strength training, but by extending the time of isometric tension of the muscles and by improving the quality of movement, which leads to strengthening without excessive mass gain. Exercises are performed on mats, without additional load, and the most often used positions in this form of training are various types of sitting and lying positions (Figure 2 and 3). Exercises can be also performed with additional accessories such as balls, elastic bands and sticks. Regular training leads to an improvement in dynamic postural control and balance, which is achieved by gradually introducing more and more complex multiplanar movements of the trunk and limbs. Pilates also positively influences the body posture, develops the movement potential and body endurance and reduces stress levels, thus affecting an overall improvement in health (Podciechowska et al., 2015; Sorosky et al., 2008; Kloubec, 2010; Mazur, Marczewski, 2011).



Figure 2. Pilates – Teaser



Figure 3. Pilates – Swimming

BodyART

BodyART is an aerobic training form created and developed by Robert Steinbacher in the 1990s. Its characteristic feature is the oriental approach to training, treating a person as an indivisible unit of the body and soul. It was created on the basis of such methods as yoga, Tai Chi, and Qi Gong. It contains elements of Chinese medicine and the Japanese system DO IN. It is also based on the Yin and Yang theory and the Chinese theory of 5 elements. Importantly, despite the inspiration from so many sources, bodyART is completely devoid of any religious or spiritual background (Podciechowska et al., 2015; Polska szkoła bodyART, www.bodyartschool.pl; BODYART International, <https://international.bodyart-training.com/info/history>; Burzawa, 2017).

BodyART exercises are performed without any additional accessories using just the weight of the body. The pace is calm and the movements smooth and harmonized with the breath. At the entry level of training, practitioners learn to maintain stable correct positions, and after achieving this skill, more and more difficult elements are introduced. Ultimately, the main content of the training is a combination of multi-articular movements in all planes with a large balance component, involving simultaneously many muscle groups (Figure 4) (BODYART International, <https://international.bodyart-training.com/info/history>; Burzawa, 2017).



Figure 4. Example of bodyART exercise

BodyART seeks to improve and maintain health with a systematic practice at least twice a week. Regular training, teaching precision and focusing on exercise techniques, forms and correct movement patterns. It improves stabilization of the body posture and acts preventively in diseases of the locomotor system. The use of relaxation exercises reduces the symptoms of fatigue and alleviates the effects of physical and mental stress (Podciechowska et al., 2015; Polska szkoła bodyART, www.bodyartschool.pl; BODYART International, <https://international.bodyart-training.com/info/history>; Burzawa, 2017).

BodyART is a safe form of training, suitable for all people regardless of gender, level of physical fitness and age. By focusing on a selected aspect – functional, therapeutic, physical or mental – the course can be differentiated and adapted to the individual needs of the practitioner. In comparison to other body & mind forms, bodyART is more dynamic, and can be an interesting alternative e.g. for people for whom Pilates or Hatha yoga are too static. For particularly demanding people looking for dynamic exercises with a greater load, trainers and people actively practicing sports, two more advanced types of training were designed – BAX (bodyART Extreme) and deepWORK (Polska szkoła bodyART, www.bodyartschool.pl BODYART International, <https://international.bodyart-training.com/info/history>; Burzawa, 2017; Tymoszewicz-Bednarz, Rodak-Dębowska, 2017).

With these mind & body practices in mind, the aim of this study was to show subjective assessment of the positive impacts of health-promoting training on physical and mental health, and to show differences in the observed effects achieved by the various forms of training – Hatha yoga, Pilates and bodyART.

Material and methods

Research tools

Our own self-assessment questionnaire was used to assess the impact of selected forms of body & mind training on the physical and mental fitness of people regularly practicing the forms. The questionnaire consisted mainly of closed type questions, in which the subjects marked the presence or absence of specific symptoms – in both the period before the start of training and after practicing the particular health-promoting form for a minimum of 2 months. The remaining questions concerned health changes observed by the subjects which occurred during their training. Additionally, on a modified 11-point Likert scale, the subjects assessed their level of satisfaction with the form, as well as their current efficiency and that prior to commencing the form. In these questions, a value of 0 meant a total lack of satisfaction with the form or the worst possible efficiency, a value of 5 meant an indifferent value, and 10 meant complete satisfaction with the form or no objections to the fitness level.

Study group characteristics

Questionnaires were distributed in fitness clubs and training studios in Krakow and the surrounding area to willing people. Finally, 81 women were qualified for the study after meeting the inclusion criteria, which included:

- female gender,
- regular participation in Hatha yoga, Pilates or bodyART training with 2 or more workouts per week lasting 60 or 90 minutes (60 minutes for Pilates and bodyART, 90 minutes for hatha yoga),
- minimum 2-month training period, measured from the start of regular training to the day of the assessment,
- no parallel sport discipline practiced during the examined period.

The subjects ($n = 81$) were divided into three groups matching the form of training – 30 (37%) in Hatha yoga, 27 (33%) in Pilates and 24 (30%) in bodyART.

The average age of the subjects in all groups was 41.4 years. In those practicing hatha yoga, the mean age of 36.6 years was significantly lower than the other groups. The mean value of the body mass index (BMI) across all subjects was 22.7. Similarly, in women practicing Hatha yoga, the mean BMI was significantly lower than in the other groups (Table 1).

Table 1. Descriptive statistics of age and BMI for the whole study group and in the particular training groups

Parameter	All				Hatha joga		Pilates		bodyART		p
	mean	SD	min	max	mean	SD	mean	SD	mean	SD	
Age [years]	41.35	11.81	17	67	36.60	12.11	45.74	11.36	42.33	10.07	0.0109
BMI [kg/m ²]	22.70	3.32	16.65	32.39	21.12	2.48	23.52	3.45	23.79	3.44	0.0032

SD – standard deviation, p – level of significance α .

For the whole study group, the length of training period was 32.7 months. The average number of trainings per one week was 2.63 (Table 2).

Table 2. Descriptive statistics of the training period and the number of training sessions for the whole study group and in particular training groups

Parameter	All				Hatha joga		Pilates		bodyART		p
	mean	SD	min	max	mean	SD	mean	SD	mean	SD	
Training duration [months]	32.68	38.35	2	200	23.30	22.08	33.74	36.94	42.21	52.21	0.1639
Number of trainings per week	2.63	1.03	2	6	2.80	1.19	2.33	0.68	2.75	1.11	0.1855

SD – standard deviation, p – level of significance α .

Statistical analysis

Statistical analyses were carried out using Statistica v13.1 (StatSoft Inc.). In order to examine the diversity of variance in the three independent groups and to determine which differences between them are statistically significant, univariate analysis of variance (ANOVA) and post-hoc Tukey tests were used. The relationships between independent and dependent groups for qualitative data was evaluated by Chi Square Pearson and McNamara tests. The T student's test for dependent groups was used to compare the average scores obtained before and after the training period. Results were considered significant at $p < 0.05$.

Results

Participants of the study assessed their satisfaction with the practiced training on a modified 11-point Likert scale. Particular values meant: 0 = "I'm not happy at all, this is the worst workout I can imagine", 5 = "I'm moderately happy, I think this training is mediocre", 10 = "I'm very happy, this is the best workout I can imagine". The lowest result indicated was 7. In the groups practicing Hatha Yoga and Pilates, the results were similar (9.53 ± 0.82 and 9.37 ± 0.97 respectively). A slightly higher mean value of satisfaction and lower standard deviation (9.83 ± 0.48) was assessed by participants of bodyART, but the difference was not statistically significant ($p = 0.1167$). For the whole study group, the average satisfaction value was 9.57 ± 0.81 .

The next parameter assessed was the subjectively perceived change in fitness which occurred as a result of practicing the chosen form. Subjects determined their physical and mental fitness on a modified Likert scale, assessing their health separately in the time before the start of regular training, and on the day of the survey. The particular values on the scale meant: 0 = "the worst efficiency that I can imagine, completely unsatisfying

me”; 5 = “average efficiency, requiring some adjustments, but relatively satisfying me”, 10 = “very good efficiency, completely satisfying me and not requiring any improvement”. The results are shown in Figure 5.

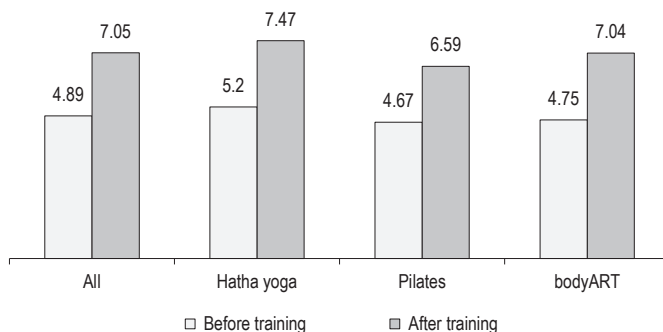


Figure 5. Comparison of general fitness self-assessment results performed by participants in whole group and particular subgroups before beginning of trainings and on the day of assessment (pts)

The results obtained before the training period were subtracted from those obtained post-workout, yielding the value of the change in fitness which occurred as a result of practicing body & mind forms. The changes in fitness for the entire study group and obtained in all training groups were statistically significant ($p = 0.0000$). For the entire study group, the average change value was 2.16 ± 1.41 . The biggest change was obtained for bodyART (2.29 ± 1.27) and Hatha yoga (2.27 ± 1.28), then Pilates (1.93 ± 1.66). Although one of the Pilates practitioners indicated that after the training period her performance deteriorated by 1 degree on the scale, the obtained results did not differ significantly between all groups ($p = 0.5753$).

Over 90% of participants in each type of training indicated that they noticed an improvement in their health that resulting from the training (Hatha yoga – 96.7%, Pilates – 92.6%, bodyART – 95.8%). Some subjects, most of whom belonged to the Pilates group (7%), reported that they did not see any change. None of the surveyed women noticed any negative impact of training on their fitness. Differences in these results were not statistically significant ($p = 0.7612$).

Subsequently, the participants were asked to indicate specific changes regarding their functioning in everyday life which could be attributed to the body & mind trainings. The most frequently marked answers in all groups were reduction of joint pain, improvement of condition and flexibility. The least frequent indicated answer was a decrease in body weight. Only for two changes the dependence with the type of training practiced was stated – an improvement of self-esteem and mental state. In both cases, the ladies who attended bodyART classes most often indicated this answer (Table 3).

Table 3. Percentage comparison of subjectively noticed changes in various health aspects after training period in particular training groups

Change	Hatha yoga [%]	Pilates [%]	bodyART [%]	p
None	0.00	3.70	0.00	0.3633
Decreased back pain	60.00	70.37	66.67	0.7052
Improved flexibility	83.33	66.67	79.17	0.3120
Improved balance	43.33	55.56	62.50	0.3560
Weight loss	20.00	14.81	16.67	0.8710
Improved endurance	60.00	48.15	70.83	0.2568
Self-esteem improvement	33.33	37.04	66.67	0.0318
Mental improvement	53.33	37.04	75.00	0.0247
Others	0.0	7.41	4.17	0.2133

In the next questions, participants pointed to the ailments they felt before the start of regular training and on the day of the survey. Statistically significant beneficial changes in physical and mental condition were observed in all groups. For the entire study group, they assessed the reduction of back, hip, knee and shoulder joint pain, improvement in the sense of balance, increase in endurance and vital energy, and improvement of the mental state. Also, the number of people who did not report any health problems increased significantly after the training. There were also significant changes specific to each form of training ($p < 0.05$). Both in the group practicing Hatha yoga and Pilates, significant changes concerned in the reduction of back pain and increased vital energy. The number of people who consider themselves completely healthy increased considerably after training in Hatha yoga. The most statistically significant changes were observed under the influence of bodyART training. In addition to the increase in vital energy and the number of people not reporting any health symptoms, this type of training also had a significant impact on the sense of balance and reduction of pain in the knee joints (Table 4)

Table 4. Comparison of health effects subjectively noticed by all participants and in subgroups practicing particular body & mind forms

Complaints	Total		Hatha Yoga		Pilates		bodyART	
	change [%]	p	change [%]	p	change [%]	p	change [%]	p
1	2	3	4	5	6	7	8	9
Spine pain	-27	0.0000	-33	0.0094	-22	0.0412	-25	0.0771
Hip pain	-17	0.0022	-13	0.1336	-22	0.0771	-17	0.2207
Knee pain	-15	0.0095	-10	0.3711	-7	0.6171	-29	0.0455
Feet Pain	-6	0.1824	-3	1.0000	-4	1.0000	-13	0.2482
Shoulder pain	-14	0.0098	-10	0.3711	-11	0.2482	-21	0.1306
Elbow pain	-1	1.0000	0	-	0	-	-4	1.0000
Wrist pain	-2	0.7237	-3	1.0000	0	-	-4	1.0000
Gait problems	-2	0.4795	-3	1.0000	-4	1.0000	0	-
Problems with balance	-15	0.0033	-10	0.2482	-11	0.6171	-29	0.0455
Limitation of joints range of motion	-5	0.1336	-3	1.0000	-4	1.0000	0	0.4795
Stress urinary incontinence	-1	1.0000	0	-	-4	0.4795	-4	1.0000
Excessive body weight	-5	0.3428	-7	0.4795	-7	0.6171	-4	0.6171

	1	2	3	4	5	6	7	8	9
Fast fatigability		-15	0.0095	-17	0.1306	-11	0.4497	-17	0.1336
Sleep problems		-6	0.1824	-7	0.6171	-7	0.6171	-4	1.0000
Lack of vital energy, feeling of permanent fatigue		-38	0.0000	-37	0.0000	-30	0.0269	-50	0.0015
Psychological problems		-14	0.0056	-13	0.1336	-15	0.1336	-13	0.3711
Others (migraines, gynecological problems)		-4	0.3711	-3	1.0000	-11	0.6171	-4	1.0000
No complaints		27	0.0000	37	0.0026	15	0.2207	29	0.0233

Discussion

The main argument for taking up the subject of this study was the small number of studies carried out so far on the health-promoting effects of practicing body & mind type trainings. The authors were also unable to find any scientific reports on the health impact of bodyART training. Only a small amount of information about this method was available, mainly in online sources, despite its popularity in fitness centres.

Among the functional changes, the reduction of joint pain and improvement of flexibility appeared to be the most frequent in all groups – described by the respondents as a feeling of easier movement in the joints, which were particularly marked by the participants of Hatha yoga. The beneficial effect of Hatha yoga on the mobility of the spine in healthy people has been demonstrated by D. Palica, A. Zwierzchowska and I. Ślężyńska (2010), assessing a group of 43 female students who practiced selected asanas as part of physical education classes for 15 weeks compared to a control group of swimming training. There was a significant improvement in flexibility in all planes in those practicing Hatha yoga, and a lack of improvement among the swimmers. What is worth noting in the initial measurements is that the Hatha yoga group showed poorer mobility than the control group. That study has also shown an improvement in posture in women practicing Hatha yoga, in the form of a slight decrease of asymmetry in the transverse plane.

Subsequently, differences in symptoms occurring before and after the period of practicing a selected pro-health form were analyzed. Over 90% of respondents in all training groups indicated that they perceived a positive effect from the practiced activity on their health, while none noticed any deterioration. These results are consistent with results of studies carried out by J. Szopa, M. Grabara and J. Górna (2009) among people aged 47-72 who practiced Hatha yoga – 100% of participants of that study felt the positive impact of training on overall fitness and mental and physical condition. Additional changes resulting from Hatha yoga were related to the reduction of perceived stress, improvements in concentration and creativity.

Similar results were obtained by W. Łubkowska (2015), who studied the effects of the participation of 60 women aged over 50 in aqua fitness classes, using a questionnaire survey. This training was relatively similar to the body & mind form because it was focused on functional exercises, forming central stability, coordination, balance and flexibility, and contained therapeutic and relaxing elements, while the respondents did not practice any other sports disciplines at the same time. In this report, an increase in overall fitness was recorded for 63% of participants, while 75% of them reported improvement in well-being and the feeling of being healthier. A comparison of these values with the results of our study allows us to suppose that the body & mind forms prevailed in therapeutic effect over those performed in water.

In our study, a significant improvement in mental state was noted for the entire study group, and a significant increase of perceived vital energy with a simultaneous decrease in the sense of chronic fatigue. The results of Pilates training were also demonstrated by M. Lipko-Kowalska (2017) in a questionnaire-based survey conducted on a group of 40 women regularly practicing this method. Mean age of the subjects was 48 years and the training period was 6 or 12 months. The respondents indicated that due to regular training they had more energy, were less stressed and more optimistic about life, and their self-esteem was higher. They also admitted that Pilates changed their lifestyle, improved their mental condition and positively influenced their social functioning. Importantly, the respondents noticed that the level of health increased with the extension of the training period, simultaneously strengthening the awareness of need for regularity to achieve the desired results. Similar results in a pilot study conducted among 30 women practicing Hatha yoga were noted by M. Sławek and R. Śleboda (2011). They stated that the level of life satisfaction, inner calm and acceptance of others rose with the extension of the training period. In addition, along with the reduction of physical and mental ailments, their sense of freedom, security and personal satisfaction increased.

The most frequently indicated benefits from the pro-health training were pain reductions in the spine and large peripheral joints. In our experiment, pain reduction in these areas was found on average in 66% of respondents. Significant changes observed in the entire study group concerned spine, hip, knee and shoulders. In particular training groups, the greatest impact of practiced activities was noted for spine joints. Significant reduction of pain in this region occurred as a result of the practice of both Hatha yoga and Pilates. Unlike, in the bodyART group, the significant difference was related to the reduction of pain in the knee joints.

The beneficial effect of 10 Pilates training sessions on pain and mobility of lumbar spine was confirmed by P. Karasiński, K. Pawłowska and J. Pawłowski (2017). They carried out research using the RMDQ and WHOQOL-BREF questionnaires and specific tests of mobility and stabilization of the trunk on a group of 30 women aged 50-65 with diagnosed degenerative disease of the lumbar spine. This training was shown to significantly reduce the pain (from 4.7 to 3.4 points in RMDQ), improving the mobility and stabilization of the lumbar spine. In addition, participants of the study assessed their quality of life higher after the training sessions. The influence of physical activity on joint pain was also examined by D. Milka, M. Jachacz-Łopata, A. Famuła, A. Brzęk and T.S. Gaździk (2011) who conducted a diagnostic survey among 118 women aged 25-60, regularly practicing aerobics in the period from 2 to 12 months. Practiced forms included whole-body training, strength training, Hatha yoga and Pilates. As a result, a reduction in spine pain in the lumbar and cervical segments was observed in over 75% of the subjects. In comparison to the values reported before starting the activity, the change was on average 3.75 points on the visual-analog scale. The values achieved in the study described above are higher than the results of our experiment, which may result from the fact that the research group consisted of people practicing different types of training, while the women included in our study practiced only one of the forms.

In our study, in the subjective feelings of the participants, the improvements in most health aspects were obtained through bodyART. In addition to the overlap of most of its effects with the results obtained in Hatha yoga and Pilates, bodyART also resulted in a significant improvement in self-perceived balance, psychological condition and self-esteem, and a significant reduction in pain of the knee joints. In the authors' opinion, the effect on the balance may result from the use of a large number of dynamic sequences in the various body positions, including equivalent positions. The reduction of knee joint pain may be affected by the performance of many exercises

strengthening the quadriceps muscle and the large number of stretching sequences of the hamstrings, which may positively affect the stability of the knee joint.

Our study has some significant limitations. First is the use of a non-standardized tool which impedes comparisons with other studies. The next limitation is the relatively small number of subjects, and last but not least, the results concern only the subjective assessment of the body & mind forms. These results could be confirmed by objective functional assessments and also compared with a control group (or groups) that represents physical activity other than body & mind training.

Despite these limitations, the results of the experiment did allow us to carefully assume that bodyART is a training that treats the person in a more holistic way than the other described body & mind forms. In the subjective opinion of participants, all the forms made significant improvements, with one form providing slightly greater effects on functioning in everyday life and improvements in health.

Conclusions

1. Regular practicing of body & mind forms can have a positive effect on subjectively perceived mental and physical health, regardless of the type of training chosen.
2. Under the influence of regular body & mind training, there are a number of positive changes in the subjectively perceived overall fitness of practitioners, the highest number of which are observed in those who practiced bodyART.

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ANIMATION OF FREE TIME AND SUPPORT FOR PSYCHOMOTOR DEVELOPMENT OF INFANTS AGED OVER 3 MONTHS

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Abstract This article constitutes a desk study regarding animation of free time and its influence on the psychomotor development of infants aged over 3 months. The article discusses the concept of free time of infants. The motor and psychological development of children between the age of three months to one year is presented. Moreover, different ways of spending free time by the parent and child are shown. The aim of this article is to raise awareness of the role of supporting early child development through appropriate selection of games and other activities in line with the individual stage of development of an infant. The article has been prepared based on a literature review (including PubMed, Research Gate, EBSCO) as well as analysis of selected offers of commercial animation activities available in the city of Poznań, taking into account the individual stages of development and their impact on the comprehensive development of infants. Moreover, a list of activities recommended for children which are adequate to specific periods of their development was also prepared.

Key words animation, free time, psychomotor development, infants

Introduction

The concept of “free time” raises many controversies regarding its meaning and definition. Some consider it as time “left after completing all necessary activities related to a person’s professional, family and social duties, as well as after performing all necessary activities related to the physiology and functioning of the body” (Kielbasiewicz-Drozdowska, 2011, p. 9). On the other hand, others argue that such time simply does not exist. The time that a person has may be divided into ‘occupied’ and ‘unoccupied’ time, with the former being spent on obligations, and the latter being dedicated to pleasure. This time is not called free time, as there are always some activities that are carried out during it (Kosiewicz, 2012). Therefore, how can the above definitions be related to infants? Is it reasonable to address the topic of free time in this age group of children? It is believed that ‘free time’ of infants will be the time ‘available’ to them after fulfilling all the physiological-hygienic-emotional duties, i.e. after feeding, sleeping, changing, bathing, and hugging. On the other hand, infants cannot decide for themselves

what they want or will do at a given moment. Most often, it is the parent – caregiver that chooses a specific form of activity to which they encourage their child. Nevertheless, voluntary participation in activities raises doubts, as free time is considered “time without obligations, which is spent on any type of activity” (Pięta, 2014, p. 11), unless voluntariness is assessed in the context of whether the child is interested or not in a given activity, by e.g. eye tracking. In that case, may it be more accurate to refer to the activity of infants to that described by J. Kosiewicz (2012)? Or is it worth looking at it strictly from the pedagogical perspective and supplement the classic definition with a child’s free time, when the parent-caregiver decides on the reasonableness and type of specific activity in the so-called free time? For this reason it is worth addressing this issue and defining such time as a period in the lives of infants which remains after all the physiological, hygienic and emotional activities, most often provided by their mother (e.g. lying in a cot or on a mat and getting to know the world from this perspective), or also arranged by the parent – caregiver, are carried out in line with the age and capabilities of the individual, while supporting their comprehensive psychological, motor and emotional development. However, it should be stipulated that with age, the children themselves will choose free time activities with the help of their parents. The way in which an infant functions in the first months of life will be reflected in their future behaviour (Carson et al., 2019). Therefore, it is important to provide a child with maximum safety and numerous types of activities that can encourage them to take up interests in the future, e.g. reading books, musical appreciation, and willingness to discover the world. By observing specific behaviours, the child begins to imitate them (Delafield-Butt, Trevarthen, 2015). Hence the great responsibility of parents for the development of future interests of their children.

The source literature underlines the importance of early stimulation of child development through play and mutual communication for their further growth. There are special programs that are intended to help parents in this area (Gladstone et al., 2018). However, one cannot forget that a child must be ready for such stimulation. The responsiveness of a small child is very strong, hence it seems worth providing them with a diversity of stimuli that may affect their future lives (Kowaluk-Romanek, Bieganowska, 2013).

Unfortunately, literature on the subject does not present homogeneous studies in the field of recreational activities for children aged 3–12 months. This is due to the fact that the issue of ‘free time’ in this age is controversial, as described above.

In the context of the above, the following research questions were formulated:

- how should ‘free time’ be organized for infants aged over 3 months to support their psychomotor development?
- which areas of child development are most significantly influenced by properly organized activities?
- who should implement animation activities with the child, and why?
- should commercial offers for infants be the only source of developmental games?

Moreover, relevant hypotheses were formulated.

Material and methods

This article attempts to determine the type and scope of animation of free time and support for the psychomotor development of infants aged over 3 months, defines and explains the validity of the concept, as well as presents a list of activities depending on the age and individual development of the child. A review of literature (including PubMed, Research Gate, EBSCO) and analysis of selected commercial activities for the aforementioned age group of children in the city of Poznań were carried out.

Psychomotor development and types of activities of infants aged over 3 months

As early as fetal life, a child grows and develops, most often for 38 weeks, to the point of finally appearing in the world and becoming an individual. This little person will have to learn about their own existence, first with the help of their caregiver, and later numerous institutions (e.g. nursery, toddler club). The way a child develops affects the behaviour of caregivers and vice versa. Therefore, it seems necessary to learn more about this stage of a toddler's life from both physical and psychological aspects.

Table 1. Psychomotor development of infants

Motor development	Psychological development
Uncoordinated movements	Ability to process visual information
Sensorimotor movements	Development of the sensory sphere
Development and improvement of locomotion	Development of manipulation
Gripping movement	Development of the emotional-social sphere
Head lifting	Development of social interactions
Sitting	
Standing	
Creeping, crawling, walking	

Source: Brzezińska, Appelt, Ziółkowska (2016); Osiński (2011); Słaboń-Duda (2011).

During infancy, the baby is characterized by uncoordinated movements that serve no purpose. These are unconditioned movements that the baby has no control of. Due to the fact that the sensory sphere is closely related to the motor sphere, attention is paid to the initially weak sensorimotor movements, which are improved thanks to the repetition of specific stimuli. The baby's locomotion, which starts from the upper to the lower parts of the body, is the most visible sphere of development for the parent. Initially, this includes turning the head to the right and left, and then lifting it. Next, the body is rotated in a lying position and grasping movements occur. The baby begins to touch various objects, clenching the hands, grasping with the entire hand, and ending with the so-called pincer grip. It is the highest-ranked movement that reflects the maturity of the nervous system in the area of grasping. The next stage is sitting, creeping, crawling, and walking (Brzezińska, Appelt, Ziółkowska, 2016; Osiński, 2011). However, it is impossible to determine which movement, be it sitting or crawling, should happen first. Some babies start sitting first, whereas others find it easier to do so from a crawling position.

Although specific developmental stages are assigned to a particular month of a baby's life, individual abilities as well as the fact that each baby develops at its own pace must be taken into account. One will raise its head at the age indicated in textbooks, i.e. 3 months, while others will reach this stage at the age of 4 months. Nevertheless, if any of the stages is overreached by several months, qualified personnel – a pediatrician, physiotherapist or osteopath – should be consulted.

Motor skills progress simultaneously with psychological development. The earliest years of a child's life are characterized by the fastest development, in particular of the nervous system, which is responsible for every sphere of life (Irwin, Siddigi, Hertzman, 2007). S.L.C. Veldman et al. (2019) believe that the development of cognitive and motor spheres are mutually dependent. Moreover, the ability to process any visual stimuli is also developed (Jacewicz, Zabłocka, 2015). The child begins to concentrate first on people it knows ('face-to-face' interaction appears) and then objects. First, they recognize the facial expressions of their parents (smile, sadness), which they

begin to imitate. Then they recognize objects from the closest surroundings, and through gripping movements, begin to develop the sensorimotor sphere. By touching, a child gets to know various structures and becomes more sensitive to, among others, a prick, or hard or soft surface. It is also the time when manipulation skills develop connected with gripping movements. This does not serve any purpose, which means that the child moves objects “just to move something”. The purposefulness of such behaviour is developed at the end of the first year of life (Brzezińska, Appelt, Ziółkowska, 2016).

At this stage, it seems extremely important to shape the bond between the parent and the child. Depending on the type: safe, avoiding, or ambivalent, not only is the relationship here and now, but also the foundation of all social interactions, including with other family members or peers (Słaboń-Duda, 2011), is shaped. Therefore, various games or fun activities are an inseparable element of the parent (in particular mother) – child interaction (Markova, 2018).

R. Przewęda (1995, p. 23) emphasizes that “a child’s knowledge about the world acquired in this period permanently enters the treasury of motoriness, as it is the basis for further activities and actions”, while the lack of exercises “impairs motor development” (Schaffer, Kipp, 2015, p. 215). In turn, a lack of intimacy means that the child will not learn how to be caring and attached to other people. The research carried out shows that infants should be encouraged to exercise freely. In order to achieve this, it is necessary to properly educate their parents (Hewitt et al., 2018). Therefore, various types of free-time activities are proposed in the caregiver (mother) – child relationship.

Table 2. Types of activities of infants over 3 months of age¹

Age	Type of activities
1	2
3 rd month	Getting to know contrast pictures (black and white, red, green, yellow) Exercises while lying on the belly that motivate the child to lift their head Music education, playing with a rattle Reading fairy tales (also with the use onomatopoeia) ‘face-to-face’ interaction Activities in water
4 th month	Short stories associated with contrast pictures (blue colour can be included) Music education (thematically related to a given activity) Games with rolling, massaging feet Reading fairy tales (also with the use onomatopoeia) ‘face-to-face’ interaction Activities in water
5 th –6 th months	Short stories related to contrasting pictures along with the use of thematic music and poems (it is worth using the movement illustration method) – while playing, it is worth using different props (e.g. toys) Games on a ball (fitball) Grabbing games (e.g. with sensory balls) Music education Rolling games Reading fairy tales (also with the use onomatopoeia) ‘face-to-face’ interaction Activities in water Socialization with peers

¹ The bold font indicates new activities for a given age or extension of previous ones

1	2
7 th –12 th months	<p>Longer thematic stories (cards/educational books) using music, poems; relating to the situation of everyday life</p> <p>Creeping games</p> <p>Games requiring the child to crawl (e.g. using a roller)</p> <p>Games related to the change of body position (getting up, walking)</p> <p>Music education</p> <p>Activities in water 'face-to-face' interaction</p> <p>Reading fairy tales (also with the use onomatopoeia)</p> <p>Socialization with peers</p>

Source: own work based on Brzezińska, Appelt, Ziółkowska (2016); Silberg (2010); Wasilewicz (2015).

The first activities from the 3rd month of life should take place at home where the child feels safe. Most often, they will consist of activities carried out by the mother and child together. Initially, the child is introduced to the outside world by being shown cards or books in white-black and black-white. Due to the formation of the organ of sight, from the third month of life, additional colours can be added in the following order: red, green, and yellow. First, the child should be laid on its back in the bed with the cards on both sides of the head, put at a distance of more or less 20 cm. The child, curious about the world, would turn its head from one side to the other. It is important to present the same picture for a few days and not change it every day. After about 5 days, it is a good idea to add a new picture. Since the child takes a relatively long time to familiarize themselves with one object, they will remember it better. In order to motivate the baby to lift their head, the child should be laid on their belly in front of a contrast card to make them interested and encouraged to lift their head. Moreover, a card or a contrast book can be put higher up. Identical exercises can be carried out with the child on an educational mat. It is important to remember that it should not be too colourful in order to not distract the child. An indispensable element of children's activity is music, the impact of which is noticeable in the prenatal period (Kołodziejcki, 2018). A child who listened to certain music during the fetal period will remember it afterwards. Beyond the 3rd month of life, it is also worth concentrating on relaxing music, especially when the infant shows signs of tiredness. While playing, rhythmic children's music with frequent repetition of lyrics, e.g. *Mucha w mucholocie* (A fly in the flyplane) or *Idziemy do zoo* (We are going to the zoo) can be used. "Music stimulates the development of the brain and the nervous system. Listened to in childhood, it affects the reception of sound stimuli throughout life, as well as helps build neuronal pathways that affect language learning, memory development and the sense of space. It also improves concentration, helps memorizing, facilitates reading, and writing, increases motivation, delays symptoms of fatigue, harmonizes muscle tone, and improves motor coordination. Frequent contact with music shapes the child emotionally and affects their willingness to learn about the world around them. Music classes conducted in groups can socialize, prevent loneliness and promote cooperation" (Wolińska, 2017, p. 262). Interest in music is the foundation for further human development in this direction (Trehub, Cirelli, 2018). At this stage, games with rattles are introduced. Reading fairy tales, poems and short stories with onomatopoeia will teach the child to focus, as well as contribute to the development of speech. It is necessary to talk to the child as much as possible so that it can create its own set of words that it will understand and identify. Over time, it will start to repeat them, initially on its own and then in the proper way. If the child is not spoken to, it will not talk back either (Wolińska, 2017). Using words such as "baa", "bleat", "bow-wow", can help children learn about the world. These words are easier for them to say than words like a "dog" or "cat". In addition to the fact that the parent helps the child learn about the world by tailoring the activity to the stage of its development, the important element is the 'face-to-face' interaction with the

parent-caregiver. The child has a sense of security, feels protected and thus creates a bond. This also affects the emotional sphere. Thanks to the fact that the parent knows their child best, they can adapt the form of activity to its individual abilities (Ferenz, 2018).

At the next stage, i.e. in the fourth month of life, short stories with contrast cards that the child has already met can be introduced. For example, cards with feet and a bear can be used to tell a short story about going on a trip to the zoo, where we will meet a bear. When using the foot motif, we can gently grab this part of the child's body and start toddling. Moreover, a prop in the form of a mascot can be used. The whole story should end with a theme song. In this case, for example, *Idziemy do zoo* (We are going to the zoo). This is the stage when child's current knowledge is broadened. The story can be implemented by movement games related to rolling and touching different parts of the body (e.g. massaging feet). This is the period when infants deliberately interact with their mother, which indicates the development of social skills of a child (Ruvolo, Messinger, Movellan, 2015).

In the 5th–6th months of life, some children are able to sit by themselves, i.e. when motor skills are more developed. It is worth enriching short stories incorporating contrast cards with the imitative method (procreative, playful) in the form of a movement story (Bronikowski, 2012), when the parent tells a story about e.g. going for a walk and saying goodbye to other family members, shows the "bye-bye" gesture, and makes the same move using the child's hand. The aforementioned story about the trip to the zoo can also be diversified by adding cards related to the weather on that day (e.g. the sun), as well as enriched with a fragment about what can be seen outside the window. Of course, the earlier motifs and props (you can add more), such as feet (the toddling motion), should be repeated. While growing up, the child will start to imitate individual movements. At this stage, the child should be strongly stimulated by movement, e.g. using a *fitball* to keep the balance of the body. Since it is the time when gripping abilities are increased, all the games associated with balance should be introduced, while taking into consideration the fact that the toddler will initially seek contact with a toy or object, and then will roughly squeeze it, and finally clench its hand (Osiński, 2011). This is also the stage when interest in peers begins – some children start going to crèches, toddler clubs, or participate in various workshops, while others spend time on the playground.

Between the 7th and 12th months of age, many changes in the child's development take place, with the main achievement being learning how to walk, taking into account all previous stages of motor development – from creeping through crawling. It is worth using rehabilitation or educational rollers to motivate the child to crawl. Due to the fact that the child is able to change position independently, they should be encouraged to exercise and make use of this ability. All basic motor skills that the child acquires during the various stages of its life, provide the basis for learning more complex movements in the future (Kordi, Nourian, Ghayour, Kordi, Younesian, 2012).

Furthermore, the child becomes more rational at this stage. Therefore, the use of this ability to socialize with others is an indispensable element of education. The infant learns to live with others, to have fun, but also to set its boundaries and territory.

In addition to the so-called 'home' activity, it is worth using the rapidly disappearing swimming reflex (Dybińska, Gedl-Pieprzycza, 1989) as well as the memory of the infant, and provide them with activity in water (Table 3), as it is the first environment in which the child began to function. Swimming lessons under the supervision of an instructor are always carried out with a parent, and this stage is characterized by "a strong need for emotional bonding with parents in children" (Dybińska, 2000, p. 13). Above all, this strengthens the bond, while ensuring a maximum sense of security. Participation in such classes improves motor activity as well as motor skills (including motor coordination), hardens the body (mentally and physically), teaches openness to others, and enables children to

interact (Sobczak et al., 2016) All classes in water start at the 3rd month. In literature, the conviction that children up to the age of 4 are not ready to take up swimming lessons can be found. This is related to, among others, safety reasons and possible drowning of the child. Nevertheless, these classes are a source of joy for children (Prevention Committee on...).

Table 3. Activities in water for infants from 3 months of age (on the example of Fregata swimming)

Offer	Supporting the development of infants
Familiarizing infants with water (3–6 months)	Familiarizing with water Integration with peers Strengthening the parent-child relationship Learning to dive, lying on back with support
Familiarizing infants with water (7–12 months)	Socializing Strengthening the parent-child relationship Acquiring new skills (independent diving, holding the edge of the pool, jumping from the edge of the pool into the water, kicking on command, breaststroke with the help of a parent)

Source: Fregata Swimming.

In addition to taking up paid activities in water (Table 3), there is also the possibility of participation of infants with their parents in animation workshops (Table 4).

Table 4. Commercial animation activities for infants aged over 6 months (examples of selected offers in Poznań)

Offer	Supporting the development of infants
Rozwojowe grupy zabawowe (Warsztaty Agaty)	Parent-child playing together (making bonds, being close) Educational and developmental games (development of the sense of balance, sight, hearing, touch, smell) Sensory games using natural materials
Zajęcia rozwojowe Taaka Głowa (Taaka Szkoła)	Strengthening the parent-child relationship First social experiences, establishing relationships Providing various stimuli Sensory games using natural materials
Niemowlandia (mammaiija)	Development of the dexterity of arms and legs (the use of the movement story method, movement games) Integration with peers Strengthening the parent-child relationship
Zajęcia rozwojowe/Gordonki (Kompozytornia)	Games and singing with the use of various means (e.g., Klanza sheet, soap bubbles, gym bags) Improving musical skills Supporting speech development

Source: Warsztaty Agaty, TAAKa Szkoła, Mammaiija, Kompozytornia.

Table 4 presents examples of commercial animation activities for children from the age of 6 months and their impact on their comprehensive development. It can be noticed that the most important element of such activities is deepening of the emotional sphere by increasing the bond between the parent and the child. In addition, the child integrates with others and acquires a variety of skills that lead to its independence. Moreover, motor, sensory and speech development is supported.

The methodological basis of each lesson is in the repetition of given activities, games, exercises, and thus a long-term action with one stimulus that helps the child learn it. Too fast a change of the existing game rules

may, for various reasons, cause less involvement on the part of the child (Fantasia, Fasulo, Costall, López, 2014). Furthermore, it is not advisable to use too many toys. All activities should be accompanied by music, reading and telling various stories. The most important element is to support the parent-child relationship. At this stage, “the family plays a fundamental role (mother, father, siblings). It is the first environment of socialization and upbringing that introduces a small child into the world of physical activities...” (Paczyńska-Jędrycka, Cieślík, 2010 p. 291). At the beginning, all activities should be carried out at home by the mother and child. Such introduction of the child into social interactions will allow it to gradually experience different behaviours and accompanying emotions (Kammermeier, Paulus, 2018). At further stages, different workshops can be used, however they should be supplemented with other activities during which the child receives and experiences a variety of stimuli. In addition to acquiring new skills and competences and gaining knowledge, a child also shapes its personality.

Regardless of the type of activity that is offered to the child, attention should be paid to the level of fatigue and the number of stimuli during one day, so that this number is not excessive. When the fatigue of an infant is noticeable, the game should be immediately stopped and the child should rest. Everything should be done in accordance with the child’s biological clock and lifestyle to positively affect the child and make sure that all activities are to their benefit, not detrimental. Too many stimuli lead to so-called overstimulation, which may have negative effects on the future life, such as, for example, the lack of ability to cope in various situations, or dealing with different emotions (Piorunek, 2013).

Summary

The concept of “free time” of infants has not yet been agreed upon in literature on the subject. However, attention has been paid to particular elements of children’s activity, namely smile games (Ruvolo, Messinger, Movellan, 2015), social games (Markova, 2018), physical activity (Hewitt et al., 2018) and music activities (Trehub, Cirelli, 2018). Moreover, literature presents opinions on the need for education of the parents in the field of broadening their awareness and skills related to activities that affect the development of a small child (Hewitt et al., 2018; Czub, Appelt, 2013). Widely understood play creates great opportunities for the development of cognitive skills – develops thinking, teaches how to express emotions and respond to various situations, including cause and effect relationships (Scott, Cogburn, 2019). It is through play that children learn to communicate, gain experience and develop imagination (Goodship, 1990).

This article is a theoretical study regarding the broadly understood topic of animation of the “free time” of infants. TDRC Pinto, DC Castro (2018) believe that animation is an innovative form of education whose objective is to support parents’ education. The aim of this paper is first and foremost to show the importance of well-organized leisure time in the psychomotor development of a young child. On one hand, the goal of the paper is to make parents and caregivers aware of the need to properly select the correct content of everyday activities. On the other hand, the paper may constitute the foundation for business entities involved in animating the time of infants. Perhaps the offer of animation courses should include exercises devoted to infants. From a practical point of view, it seems necessary to conduct research on this subject.

Conclusions

1. In regards to literature as well as the analysis of exemplary workshops, free time for infants aged over 3 months should be organized in order to support their psychomotor development.

2. Free time activities of infants aged over 3 months should be fun as well as be adapted to the individual development of the child, taking into account the aspect of versatility – the motor and psychological sphere (including emotional and interpersonal interactions). Moreover, the pace of child development, which cannot be accelerated but can be supported, should be taken into consideration.

3. All animation content with an infant should be carried out in the closest environment between the child and the parent. This is where the child is in its comfort zone and feels safe.

4. All offers regarding free time activities of infants which are available on the market may be used, provided that they do not constitute the only source of entertainment. Free time activities can be carried out at home from the 3rd month of life, and during workshops from the 6th month. The exceptions are classes related to familiarizing the child with water. Providing a sufficient amount of new stimuli to the child will affect them positively and influence the physical, psychological and spiritual spheres. All these spheres are strongly connected with each other. A deficiency in one will affect the other. Therefore, the child should not be influenced unilaterally but rather comprehensively.

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THE STRENGTH OF LOWER LIMBS IN ELITE GYMNASTS AND SWIMMERS

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Abstract Critical moments during gymnastic exercises are those related to landing and suppressing overloads, transmitted through lower limbs. A swimmer's lower limbs provide a good body position in the water and maintain the balance. Both in sports authors postulate reaching bilateral, steady development of the athlete's body.

The main aim was identification and a comparative analysis of the hip, knee and ankle joints flexors and extensors strength, of highly qualified gymnasts and swimmers.

Ten healthy subjects participated in the investigation. Five gymnasts (22.2 ± 7.3 y.o., 169.4 ± 3.91 cm, 64.4 ± 3.78 kg) and five swimmers (20.5 ± 1.3 y.o., 186.2 ± 1.64 cm, 78.4 ± 2.61 kg) were highly qualified Polish athletes.

Strength measurements were made on Biodex S4 isokinetic dynamometer. Subjects performed hip extension/flexion in lying position, knee extension/flexion and ankle plantar/dorsi flexion.

Strength parameters of the lower limbs differentiate gymnasts and swimmers.

Lower limb's strength parameters can be used during training, control, selection or prevention. To achieve a high sport level, swimmers must demonstrate higher strength parameters of lower limbs than gymnasts. The value of work in the maximum repetition (MRW) should be thoroughly analyzed. Highly qualified gymnasts and swimmers should take into account the harmonious, bilateral strength development of the lower limbs.

Key words lower limbs, strength, Biodex, gymnasts, swimmers

Introduction

Sport performance is a special manifestation of human functioning during which particular body systems often work in conditions of maximum potential. Even the hardest professional work does not cause in the human body such adaptive changes that occur in master class athletes (Bołoban, Wiśniowski, Mistułowa, Niżnikowski, 2003; Sadowski, Bołoban, Mastalerz, Niżnikowski, 2003). Muscle strength affects all aspects of human activity. It is treated as a measure and index of health. The development of muscular strength and keeping it at a constant high

level is of great importance in sport, correction and rehabilitation. It is the basis of all forms of physical activity and a parameter that determines the development of other motor abilities (Jensen, Smith, Johnson, 1971; Wit, 2002).

Gymnasts are exposed to large overloads of the musculoskeletal and articular system, which often leads to injury. In the case of sport gymnasts, the whole skeletal system is exposed to injuries due to the specificity of the discipline (six events requiring a performer to move in space, perform complex elements and landings). The gymnasts' arms are most often exposed to symmetrical, bilateral loads added to the upper limbs (Gerhardt, Doyscher, Boschert, Scheibel, 2014). However, trainers shouldn't play down the role of lower limbs. The critical moments during the exercises are those related to landing and suppressing overloads. Ground reactions exceed 10,000 N and are transmitted through the ankle joint to the knee and hip joints (Bober, Hay, 1991; Kędzior, Nawiński, Wit, 1992; Czajka, Wiśniowski, Sacewicz, 2016). Incorrect performance of the exercise, caused by bad technique or musculoskeletal system dysfunction, may result in mechanical damage to the joints.

Swimmers and gymnasts train in artificially created conditions (swimming pool – water environment, gymnastic devices). The position of a swimmer is unusual for a human – horizontal, and the work done in the training process is in a different environment than gymnasts (constant water resistance, constant movement). The speed of swimming depends on many factors. As one of the most important, the strength abilities of a swimmer are mentioned. While training in a swimming pool, a swimmer stays in motion all the time, which significantly strains the musculoskeletal system. The basic drag force of athletes practicing sports swimming is generated by the arms (Troszczyński, 1999; Przybylska, 2010). Nevertheless, many authors (Bogajewski, Roszko, Witkowski, Wróbel, 1969; Bartkowiak, 1972, 1984; Troszczyński, 1999; Przybylska, 2010) report that the proper functioning of the lower limbs provides a good body position in the water and maintains the balance. The work of the lower limbs is as important as the upper limbs, although the legs do not give such a large propelling force (Bartkowiak, 1984; Laughlin, 2007; Montgomery, Chambers, 2009). The most common injuries occurring in swimming include various permanent and chronic upper limb injuries: bruises, wounds, painful shoulder syndrome (functional instability of the glenohumeral joint), rotator cuff injury, bicep arm inflammation, shoulder dislocation. However, there are also injuries of the lower limbs, i.e. the "swimmer's knee" or pain syndrome of the patellofemoral joint (Czabański, Filon, Zatoń, 2003).

Both in swimming (Alonso-Cortés Fradejas et al., 2006; Wiażewicz 2015; Wiażewicz, 2016) and gymnastics (Jurkojć, Michnik, Skubacz, Ziółkowska, 2012; Gerhardt et al., 2014) authors postulate reaching bilateral steady development of the athlete's body. It is reported that deficits in strength between body sides and the agonists to antagonists strength ratio are important in injury prevention of these athletes. Improper proportions in strength between the right and left sides or between particular muscle groups can result in poor posture during gymnastic events and inadequate stabilization of each joint or the entire body. This may result in micro-injuries as well as more frequent trauma (Jurkojć et al., 2012). This may also lead to unwanted torso rotation, changes in swimming techniques and reduced mobility in the water (Sanders, 2013).

Main aim

The main aim of this study was identification of the hip, knee and ankle joint flexor and extensor strength, in highly qualified athletes practicing gymnastics and swimming. The next objective was a comparative analysis of the gymnasts' results with the results of the swimmers in each movement, in the examined joints. The results provided answers to the following research questions:

1. What values are the selected strength parameters in highly qualified gymnasts and swimmers?

2. Do the results differentiate the examined groups?
3. Which parameter differentiates the examined groups the most?

Methods

Ten healthy subjects (five gymnasts and five swimmers) participated in the study. The gymnasts (22.2 \pm 7.3 years old, 169.4 \pm 3.91 cm, 64.4 \pm 3.78 kg) were highly qualified Polish athletes. Two of them were Master of Sports International Class (MM), one was Master of Sports (M) and two were 1st class (I). The participants were informed about the task and gave their written permission for the tests. The second group were swimmers (20.5 \pm 1.3 years old, 186.2 \pm 1.64 cm, 78.4 \pm 2.61 kg). They were high class athletes from the City Swimming Club in Szczecin (MKP). Two subjects were Master of Sports (M), while three of them were Master of Sports International Class (MM). Participants were informed about the task and gave their written permission to the test. The Bioethics Committee at the Regional Medical Chamber in Szczecin gave a positive opinion about the research project (resolution No. 15/KB/V/2013 dated 10.12.2013 r.) – applies to the swimmers.

First, the subjects performed a 5-minute warm up on a stationary bike, then a 5-minute warm up focused on the investigated joint. Strength measurements were made on a Biodex S4 isokinetic dynamometer (Biodex Corp., Shirley, NY, USA). During the test, the subjects performed hip extension/flexion in a lying position, knee extension/flexion and ankle plantar/dorsi flexion in two different protocols. The number of repetitions and angular velocity are presented in Table 1. There was a 2-minute break between protocols and a 4-minute rest between right and left limb measurement. Preparation and the measurement were made according to Biodex Medical Systems, Inc. (Biodex, 2019a). Each joint was tested on a different day.

Table 1. Number of repetitions and angular velocity in Protocols 1 and 2 in the tested joints

Joint	Pattern	Protocol 1		Protocol 2	
		Repetitions	Angular velocity (°/s)	Repetitions	Angular velocity (°/s)
Hip	Flexion/Extension	5	45	10	300
Knee*	Extension/Flexion	5	60	10	180
Ankle	Plantar/Dorsi Flexion	5	30	10	60

* Gravity correction was applied.

Values: peak torque (PT), peak torque to body weight ratio (PT/BW) and maximal repetition work (MRW) were used from protocol 1. Values: work to body weight ratio (W/BW), total work (TW), work fatigue (WF), average power (AP), average peak torque (APT) and agonist to antagonist ratio (AG:AN) were taken from protocol 2. All were measured for both movements in the tested joints. In order to determine the asymmetry value, the percentage deficits of the selected strength parameters (PT, MRW, TW and AP) were analyzed.

For statistical analyses, Statistica v13.5 was used. A Shapiro-Wilk test (significance level 0.05) was used to check whether samples came from a normally distributed population. T-Test: two-sample assuming equal variances was used (significance level 0.05), when the result of Shapiro-Wilk's test wasn't significant in both compared variables, so samples came from a normally distributed population. Results were presented as mean (\bar{x}) and standard deviation (SD). Otherwise, when the result of Shapiro-Wilk's test was significant in at least one of the two compared variables, samples did not come from a normally distributed population and a nonparametric Mann-Whitney U test was used. In this case the median and the quartile gap were presented.

Results

Results from the hip joint investigation are presented in Table 2. Almost all average maximum strength parameters from protocol 1 (PT, PT/BW, MRW) measured in the hip joint movements were significantly higher for swimmers than gymnasts. Right hip extension movement presented almost three times significantly greater values for W/BW, TW and AP in swimmer than in gymnasts. In hip flexion APT was higher for gymnasts – significant difference only for the left joint. But the same parameter in extension was almost twice higher for swimmers, with significant differences only for the right joint. Differences between both groups in AG:AN ratio were significant. Average values were more than twice higher from the gymnasts.

Table 2. Comparison of gymnasts and swimmers hip strength parameters

			Gymnasts		Swimmers		p
			\bar{x}	SD	\bar{x}	SD	
PT	Flexion	Right (Nm)	84.9	14.64	133.2	26.75	0.007587 [*]
		Left (Nm)	72.0	17.09	143.2	35.62	0.003808 [*]
	Extension	Right (Nm)	98.4	14.81	206.0	55.33	0.002990 [*]
		Left (Nm)	76.2	18.89	210.6	56.35	0.000984 [*]
PT/BW	Flexion	Right (%)	132.1	21.58	171.6	29.43	0.041508 [*]
		Left (%)	111.6	23.20	185.1	39.93	0.007448 [*]
	Extension	Right (%)	152.8	19.72	266.0	62.57	0.004830 [*]
		Left (%)**	112.2	25.6	288.4	25.50	0.007937 [*]
MRW	Flexion	Right (J)	58.6	6.70	117.3	21.37	0.000378 [*]
		Left (J)	42.9	9.30	113.3	5.31	0.000000 [*]
	Extension	Right (J)	58.4	15.89	178.2	48.61	0.000787 [*]
		Left (J)	43.0	14.38	178.5	49.72	0.000380 [*]
W/BW	Flexion	Right (%)	40.5	17.59	40.1	16.48	0.967008
		Left (%)	35.8	10.78	26.8	11.08	0.230133
	Extension	Right (%)	41.9	14.25	108.8	53.96	0.027913 [*]
		Left (%)	38.7	11.64	93.6	61.71	0.086151
TW	Flexion	Right (J)	215.6	124.66	237.1	114.63	0.784296
		Left (J)	185.8	73.68	134.1	62.56	0.266274
	Extension	Right (J)	230.2	89.58	661.5	348.58	0.027932 [*]
		Left (J)	208.3	70.38	550.2	364.97	0.073724
WF	Flexion	Right (%)**	-11.6	9.80	20.1	68.30	0.916815
		Left (%)	-28.9	37.17	-30.7	83.40	0.967434
	Extension	Right (%)	-8.6	18.42	-42.3	51.94	0.208949
		Left (%)	1.1	30.52	-37.5	53.75	0.199475
AP	Flexion	Right (W)	58.5	42.13	61.8	35.20	0.895772
		Left (W)	51.6	26.84	35.4	17.26	0.288527
	Extension	Right (W)	69.1	35.96	198.8	115.76	0.043685 [*]
		Left (W)	59.6	34.28	162.3	106.55	0.074162
APT	Flexion	Right (Nm)	55.1	16.80	44.3	19.13	0.372306
		Left (Nm)	47.9	11.51	25.2	8.55	0.007585 [*]
	Extension	Right (Nm)	47.4	13.67	101.7	49.37	0.045058 [*]
		Left (Nm)	45.1	17.00	95.7	54.84	0.084140
AG:AN	Right (%)	116.3	38.28	49.6	11.80	0.005853 [*]	
	Left (%)	110.8	31.13	35.8	12.28	0.001034 [*]	

^{*} Difference between both groups is significant ($p < 0.05$).

^{**} A nonparametric Mann-Whitney U test was used. Results are median and the quartile gap.

Table 3 presents a comparison of the gymnasts and swimmers knee strength. Similarly to the hip joint, almost all PT, PT/BW, MRW values were significantly higher for the swimmers than gymnasts. In all protocol 2 parameters the differences between groups were non-significant. But almost every value was higher for the swimmers.

Table 3. Comparison of gymnasts and swimmers knee strength parameters

			Gymnasts		Swimmers		P
			\bar{x}	SD	\bar{x}	SD	
PT	Extension	Right (Nm)	126.8	35.92	229.2	40.43	0.002855*
		Left (Nm)	128.6	15.32	231.0	37.91	0.000509*
	Flexion	Right (Nm)	72.3	11.10	119.5	19.55	0.001552*
		Left (Nm)	69.8	12.33	120.4	8.67	0.000069*
PT/BW	Extension	Right (%)	196.4	49.02	302.1	49.90	0.009658*
		Left (%)	199.5	13.31	304.5	46.11	0.001208*
	Flexion	Right (%)	112.0	11.13	157.2	21.40	0.003007*
		Left (%)	108.4	16.96	158.7	6.92	0.000278*
MRW	Extension	Right (J)	129.6	44.25	289.2	49.70	0.000676*
		Left (J)	126.9	19.27	275.4	40.63	0.000077*
	Flexion	Right (J)	79.1	28.43	165.8	19.72	0.000511*
		Left (J)	75.2	19.07	158.4	21.15	0.000182*
W/BW	Extension	Right (%)	197.3	70.28	238.2	105.04	0.490307
		Left (%)**	190.3	63.40	286.0	129.70	0.222222
	Flexion	Right (%)	115.3	27.84	131.0	56.93	0.595640
		Left (%)	106.8	14.09	133.1	28.65	0.103450
TW	Extension	Right (J)**	1,130.3	512.10	2,128.7	1,497.00	0.690476
		Left (J)	998.9	253.10	1612.2	588.82	0.064805
	Flexion	Right (J)	637.7	183.88	794.5	514.31	0.538825
		Left (J)	582.6	107.37	870.7	262.30	0.052635
WF	Extension	Right (%)**	2.5	6.90	13.4	90.90	0.841270
		Left (%)	-12.3	23.94	-6.4	29.04	0.733277
	Flexion	Right (%)**	6.8	6.00	20.1	354.00	0.916815
		Left (%)**	-4.2	27.90	5.5	78.00	0.547619
AP	Extension	Right (W)	165.2	52.90	213.8	124.03	0.444116
		Left (W)	164.3	35.86	238.6	95.22	0.140861
	Flexion	Right (W)	93.9	25.24	111.0	77.12	0.650833
		Left (W)	89.9	16.45	127.3	48.47	0.141528
APT	Extension	Right (Nm)	87.5	26.45	114.6	61.92	0.394733
		Left (Nm)	90.0	16.13	130.0	49.32	0.122874
	Flexion	Right (Nm)	50.9	8.90	62.7	38.42	0.521620
		Left (Nm)	52.9	5.76	72.4	23.23	0.105682
AG:AN	Right (%)**	53.7	4.60	58.6	2.10	0.420635	
	Left (%)	56.0	13.09	58.9	8.93	0.687078	

* Difference between both groups is significant ($p < 0.05$).

** A nonparametric Mann-Whitney U test was used. Results are median and the quartile gap.

Strength parameters from ankle joint testing are presented in Table 4. A greater number of the presented values were higher for the swimmers. Average MRW was about twice times significantly lower for gymnasts than swimmers. Significant differences were observed in W/BW values (higher in swimmers), non-significant only in W/

BW right ankle dorsi flexion. In plantar flexion TW was again significantly higher for swimmers in both sides. In dorsi flexion the significant difference was only noticed for the right side. Ankle WF parameter was higher in swimmers and the difference was significant only in dorsi flexion.

Table 4. Comparison of gymnasts and swimmers ankle strength parameters

			Gymnasts		Swimmers		p
			\bar{x}	SD	\bar{x}	SD	
PT	Plantar Flexion	Right (Nm)	71.5	20.37	113.8	46.89	0.101429
		Left (Nm)	70.9	12.76	105.6	35.65	0.074745
	Dorsi Flexion	Right (Nm)	25.4	3.75	28.0	4.29	0.341231
		Left (Nm)	25.0	5.88	26.4	3.40	0.643657
PT/BW	Plantar Flexion	Right (%)	110.3	27.00	147.2	57.66	0.231383
		Left (%)	110.5	20.63	136.7	43.56	0.258861
	Dorsi Flexion	Right (%)	39.5	4.29	36.3	4.55	0.291262
		Left (%)	38.6	7.66	34.2	3.09	0.269587
MRW	Plantar Flexion	Right (J)	27.5	9.32	65.2	18.76	0.003831*
		Left (J)	26.0	4.72	63.0	20.40	0.004217*
	Dorsi Flexion	Right (J)	9.1	2.73	18.2	3.04	0.001066*
		Left (J)	9.7	3.43	18.2	3.97	0.006838*
W/BW	Plantar Flexion	Right (%)	48.6	10.19	75.5	23.66	0.047663*
		Left (%)	46.7	8.03	76.6	26.10	0.039956*
	Dorsi Flexion	Right (%)	11.7	3.75	17.8	4.89	0.057863
		Left (%)	11.6	4.00	18.2	4.89	0.047187*
TW	Plantar Flexion	Right (J)	271.9	63.80	493.5	135.72	0.010787*
		Left (J)	235.2	59.89	479.0	179.44	0.020433*
	Dorsi Flexion	Right (J)	62.8	22.03	94.9	21.28	0.047369*
		Left (J)	60.5	27.52	97.0	24.20	0.056561*
WF	Plantar Flexion	Right (%)	1.4	18.10	10.3	15.51	0.424998
		Left (%)	4.1	14.47	12.0	14.32	0.414117
	Dorsi Flexion	Right (%)	32.0	13.29	52.4	8.51	0.020005*
		Left (%)	31.9	9.47	52.6	4.90	0.002419*
AP	Plantar Flexion	Right (W)	43.6	6.80	52.5	18.07	0.335871
		Left (W)	40.0	5.01	47.3	19.04	0.434622
	Dorsi Flexion	Right (W)	9.1	2.53	9.9	3.16	0.662408
		Left (W)	8.9	2.65	9.0	2.36	0.961066
APT	Plantar Flexion	Right (Nm)	63.5	12.94	83.9	26.77	0.163909
		Left (Nm)**	55.5	2.50	80.3	29.90	0.309524
	Dorsi Flexion	Right (Nm)	16.5	3.00	16.8	3.91	0.902020
		Left (Nm)	16.3	3.34	16.3	2.72	0.983922
AG:AN	Right (%)	26.8	5.95	24.0	8.16	0.552489	
	Left (%)	28.2	7.80	25.4	11.40	0.657907	

* Difference between both groups is significant ($p < 0.05$).

** A nonparametric Mann-Whitney U test was used. Results are median and the quartile gap.

Table 5 presents the deficits of selected strength parameters for hip joints. The deficits of PT, MRW, TW and AP parameters between the hips, in both movements were lower in swimmers (the exception was a TW deficit in flexion), but a significant difference existed only for the MRW parameter during flexion.

Table 5. Comparison of gymnasts and swimmers hip strength deficits between sides

			Gymnasts		Swimmers		p
			\bar{x}	SD	\bar{x}	SD	
PT	Flexion	Deficit (%)	15.5	12.45	13.3	8.33	0.753188
	Extension	Deficit (%)	24.8	11.52	10.4	9.08	0.059386
MRW	Flexion	Deficit (%)	33.8	14.74	13.4	7.91	0.026432*
	Extension	Deficit (%)	37.6	19.36	16.6	6.38	0.050213
TW	Flexion	Deficit (%)	30.0	18.71	37.8	26.28	0.601624
	Extension	Deficit (%)	28.5	22.31	16.8	22.10	0.431191
AP	Flexion	Deficit (%)	39.1	31.63	35.4	25.61	0.844807
	Extension	Deficit (%)	37.0	28.09	19.1	22.68	0.298796

* Difference between both groups is significant ($p < 0.05$).

Comparison of strength parameter deficits for knee joints of gymnasts and swimmers is presented in Table 6. PT and MRW deficits were higher for gymnasts in both movements, with a significant difference only for MRW in extension. In contrast, almost all TW and AP deficits were higher for swimmers (except for the AP deficit in knee extension).

Table 6. Comparison of gymnasts and swimmers knee strength deficits between sides

			Gymnasts		Swimmers		p
			\bar{x}	SD	\bar{x}	SD	
PT	Extension	Deficit (%)	15.7	14.91	2.5	2.79	0.088308
	Flexion	Deficit (%)	14.2	5.38	10.5	3.86	0.244279
MRW	Extension	Deficit (%)**	20.5	12.80	1.0	1.50	0.031746*
	Flexion	Deficit (%)	21.4	16.02	11.7	11.23	0.298863
TW	Extension	Deficit (%)	15.4	11.58	29.8	38.47	0.446065
	Flexion	Deficit (%)**	5.6	22.80	19.1	35.90	0.309524
AP	Extension	Deficit (%)**	20.7	7.80	13.1	23.00	0.690476
	Flexion	Deficit (%)**	12.3	8.50	21.8	39.50	0.547619

* Difference between both groups is significant ($p < 0.05$).

** A nonparametric Mann-Whitney U test was used. Results are median and the quartile gap.

Table 7. Comparison of gymnasts and swimmers ankle strength deficits between sides

			Gymnasts		Swimmers		p
			\bar{x}	SD	\bar{x}	SD	
PT	Plantar Flexion	Deficit (%)	35.5	36.04	10.8	4.87	0.166995
	Dorsi Flexion	Deficit (%)	8.3	5.66	6.0	5.10	0.522022
MRW	Plantar Flexion	Deficit (%)	29.3	27.67	18.7	13.47	0.463350
	Dorsi Flexion	Deficit (%)	10.9	9.61	12.3	11.59	0.838225
TW	Plantar Flexion	Deficit (%)	23.4	18.15	20.2	16.03	0.772439
	Dorsi Flexion	Deficit (%)	11.1	11.79	14.7	10.19	0.613750
AP	Plantar Flexion	Deficit (%)	13.6	12.01	11.6	6.15	0.756068
	Dorsi Flexion	Deficit (%)	6.0	3.21	8.8	5.83	0.367489

Table 7 presents a comparison of deficits in selected strength parameters for the ankle joint. The differences between the deficits of all the presented strength parameters were lower for swimmers in the plantar flexion. However, in the movement of the dorsi flexion the results of swimmers were higher than gymnasts (except for the PT deficit). All described differences were not statistically significant for both movements.

Discussion

The results present values of selected strength parameters from highly qualified gymnasts and swimmers.

Hip joint PT of the gymnasts and swimmers were much higher than presented by Biodex (2019a) 13.4 Nm in flexion and 21.0 Nm in extension. The same was observed in hip PT/BW flexion (17.4%) and extension (27.4%). It is probably due to the fact that Biodex (2019a) presented the results of non-training subjects.

P.A. Garcia, J.M. Dias, R.C. Dias, P. Santos, C.C. Zampa (2011) presented hip joint AP parameters for 65–69, 70–79 and 80+ y.o. seniors. Both analyzed parameter sets were lower in the 65–69 and 70–79 y.o. seniors (83.6 \pm 30.9 W; 67.4 \pm 27.2 W) in hip flexion AP. In hip extension movement the seniors AP (24.1–47.6 W) were much lower than gymnasts and swimmers. But it must be noticed that different angular velocities were used.

The APT for the dominant limb in hip flexion showed that gymnasts and swimmers were much lower than 65–69 and 70–79 y.o. seniors (74.7 \pm 24.2 Nm; 63.1 \pm 24.0 Nm) (Garcia et al., 2011). APT values in gymnasts hip extension were just few percentages higher than 70–79 y.o. seniors (44.4 \pm 23.2 Nm) (Garcia et al., 2011). Swimmers were more than 2 times higher than this. These unusual results are probably due to different angular velocities used in the measurement protocols.

Gymnasts presented almost four times higher values of AG:AN ratio than Biodex (2019a) (29%). Swimmers also were higher than this, but as much as gymnasts. Greater balance of hip joint agonists and antagonists muscles can be seen in gymnasts than swimmers.

Results of these studies confirmed the thesis of T.D. Cahalan, M.E. Johnson, S. Liu, E.Y. Chao (1989). In their results hip extensors were stronger than flexors (regardless of age or gender). The same was in both researched groups.

Gymnast and swimmer PT and PT/BW measured in knee extension was greater than that showed by Biodex (2019a) (28.7 Nm; 38.4%). Swimmer knee extension PT was almost the same as that presented by R. Dotan et al. (2013) for untrained men (22.9 y.o.) – 226.2 \pm 42.5 Nm, and at the same time, a bit higher than almost 19 y.o. male professional soccer players (Daneshjoo, Rahnama, Mokhtar, Yusof, 2013) – 201–209 Nm. Gymnasts were almost twice lower in the same strength parameter and movement. They archived values similar to older women (113–115 Nm) (Hakestad, Nordsletten, Torstveit, Risberg, 2014). This can be alarming. The same was observed in knee flexion PT. A. Daneshjoo et al. (2013) presented values of 100–102 Nm for young soccer players. It was higher for gymnasts and lower for swimmers, in this study.

In knee extension movement, TW parameter presented by gymnasts was lower than 50+ y.o. women (1,480–1,536 J) (Hakestad et al., 2014). This can be caused by a lack of strength endurance training in this particular joint and movement. Swimmers results were much higher than this.

Both gymnasts and swimmers were much higher in knee AP in extension and flexion movements than seniors results (68.9–109.9 W; 23.8–43.2 W) (Garcia et al., 2011).

The APT parameter for investigated gymnasts and swimmers in knee extension was from more than 1.2 to almost 3 times higher than seniors (45.3–67.7 Nm) (Garcia et al., 2011). The same strength parameter in knee

flexion were even more times higher than those presented by P.A. Garcia et al. (2011) (18.9–31.1 Nm). The APT parameter in knee flexion was from more than 1.5 to almost 4 times higher than seniors (18.9–31.1 Nm). Same strength parameter in knee extension was not so many times more than seniors (45.3–67.7 Nm) (Garcia et al., 2011) like above, but also higher in the investigated gymnasts and swimmers.

The knee AG:AN ratio presented by young male professional soccer players (Daneshjoo et al., 2013) was on average 50%. Gymnasts were just a few percentage points higher and swimmers presented almost 9% more in the same parameter. Knee AG:AN results of non-training subjects (Biodex, 2019a) were much higher (72%) than in this study, showing that professional sport can decrease the AG:AN knee ratio.

Measured ankle PT parameter in plantar flexion, for gymnasts were 4 to 5 times higher than showed by untrained subjects in Biodex (2019a) (16.4 Nm). But for swimmers it was almost 7 times more.

The same was observed in PT/BW values in the same movement for both groups in comparison to Biodex (2019a) data – 21.7%. Ankle dorsi flexion PT values were about 6 times higher in gymnasts and swimmers than in untrained people (4.3 Nm). In the same movement PT/BW values were 6–7 times higher than non-training people (5.7%) (Biodex, 2019a).

B.A. Lee, S.H. Lee, D.J. Oh (2013) showed the results of the ankle joint for male university students representing modern pentathlon (21.00 ±1.15 y.o.). Ankle plantar flexion PT (74.49 ±16.89 Nm) was just a few percentage points higher than gymnasts and much lower than swimmers. PT in ankle dorsi flexion (≈20 Nm) was higher for both groups. But the results were measured in 60°/sec angular speed.

In ankle joint plantar flexion, both gymnasts and swimmers were almost 2 times lower in PT/BW parameter than gymnasts (182.45–189.99%; 22.9 y.o.) and control group (185.84–191.01%; 22.8 y.o.) presented by S.T. Aydog et al. (2005). PT/BW in dorsi flexion showed that gymnasts in our research were close to gymnasts investigated by S.T. Aydog et al. (2005) (36.79–46.53%) but lower than controls (47.71–51.81%). Swimmers were lower than both presented groups.

Gymnast and swimmer ankle APT in plantar flexion was higher than presented by seniors (24.9–47.2 Nm) (Garcia et al., 2011). The APT in dorsi flexion movement was higher than showed by 70–79 and 80+ y.o. (12.2–14.7 Nm), but also almost the same as 65–69 y.o. people (16.8 ±5.7 Nm) (Garcia et al., 2011).

The AG:AN ratios for ankle joints of gymnasts and swimmers were just few percentage points lower than showed by Biodex (2019a) – 31% or S.T. Aydog et al. (2005) – 26.24–29.02% in untrained people. Gymnasts in our study presented few percentages higher values than gymnasts in other research (Aydog et al., 2005) (23.34–25.03%). This can prove that gymnastic and swimming training does not affect agonists to antagonists ratios in ankle joints.

All of the hip strength deficits were higher than acceptable (1–10%) (Biodex, 2019b). Only swimmers PT deficits in flexion, in extension and MRW deficit in flexion movement were close to the considered limit. For gymnasts all of them were above.

According to Biodex (2019b) values (1–10%), in knee joint, percentage differences between sides were acceptable only in flexion TW for gymnasts and extension PT or MRW in swimmers. Side deficits for gymnasts knee flexion AP and swimmers knee flexion PT, MRW and extension AP were near the proposed limit. In comparison, the PT deficits for young male professional soccer players (Daneshjoo et al., 2013) were higher in flexion movement (19.6%) than both gymnasts and swimmers, but in extension (13.8%) only swimmers showed lower values.

In ankle joint dorsi flexion PT and AP deficits, both gymnasts and swimmers were within the recommended limit $\leq 10\%$ (Biodex, 2019b). Other values, measured in the ankle joint, like MRW deficit, TW deficit in dorsi flexion or AP deficit in plantar flexion for gymnasts and PT deficit, AP deficit in plantar flexion or MRW deficit in dorsi flexion for swimmers were close but not within the limit of 10%.

Measuring nine selected parameters, on both sides of the body (right and left lower limb), in two movements (flexion and extension or plantar and dorsi flexion – depending on measured joint) gave 34 strength parameters to compare between the examined groups for each tested joint.

In the hip joint we observed that 19 out of 34 parameters differed significantly between gymnasts and swimmers. Parameters were mostly related to the first “maximal strength” protocol. The analysis of knee joint presented 12 strength parameters, where differences between the examined groups were significant. They were related only to the first “maximal strength” protocol. Also in the ankle joint, there were 12 parameters that differed significantly between gymnasts and swimmers. In the majority they were related to the second “endurance-strength” protocol.

All of the results can give the conclusion that lower limb strength parameters differentiate highly qualified gymnasts and swimmers. The differences are probably caused by the specificity of the disciplines and the dissimilarity of training.

Analyzing differences between the gymnast and swimmer groups, the lowest p value was observed in MRW flexion. For the knee joint the p value was lowest in MRW in extension movement and PT in flexion movement. Also in the ankle joint, the MRW in both dorsi and plantar flexion had the lowest p value. The MRW parameter was the one that differed gymnasts and swimmers the most, regardless of the examined joint.

Analyzing the strength parameter deficits, there were four for each joint, measured in both movements (flexion and extension or plantar and dorsi flexion – depending on the measured joint). That gave 8 deficits for each joint to analyze.

For hip strength deficits only MRW in hip flexion differed significantly between gymnasts and swimmers. In knee analysis, only in MRW deficit in extension movement the difference between groups was significant. None of the ankle joint strength deficits between sides were significant.

Only for hip and knee joints, 1 out of 8 deficits differed significantly. There was no significant difference between gymnast and swimmer deficits in ankle joints. This confirms the necessity of reaching bilateral development of the athlete's body (Alonso-Cortés Fradejas et al., 2006; Jurkojć et al., 2012; Gerhardt et al., 2014; Wiażewicz, 2015; Wiażewicz, 2016) in both, gymnastics and swimming, despite the discipline dissimilarity or training environment.

Conclusions

The obtained values of strength parameters for hip, knee and ankle joints from highly qualified athletes practicing gymnastics and swimming can be used in the training process, during control or selection, or to prevent injuries.

In order to achieve a high sport level, swimmers must demonstrate higher values of lower limbs strength parameters than gymnasts.

In the sport selection process in gymnastics and swimming, the value of work in the maximum repetition (MRW) of the lower limbs should be thoroughly analyzed.

Training of highly qualified athletes practicing gymnastics or swimming should take into account the harmonious bilateral strength development of the lower limbs.

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