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COMPARATIVE ANALYSIS OF SOMATIC PARAMETERS AND MOVEMENT QUALITY IN NOVICE AND EXPERIENCED CROSSFIT ATHLETES

Piotr Sporek[A, B, D]

Faculty of Physical Education and Physiotherapy, Opole University of Technology, Opole, Poland
ORCID: 0000-0002-3945-8233| e-mail: p.sporek@po.edu.pl

Mariusz Konieczny[C, E]

Faculty of Physical Education and Physiotherapy, Opole University of Technology, Opole, Poland
ORCID: 0000-0001-7995-0882

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Abstract In this study, fifty active CrossFit athletes were divided into beginner (n = 25, mean age 24.8 ±5.2 years) and experienced groups (n = 25, mean age 25.1 ±4.9 years) to assess injury risk, body fat distribution, and functional movement quality at different levels of experience. All participants attended training sessions five times a week and were preparing for competitions, training CrossFit at a competitive level, with the beginner group having up to 2 years of CrossFit training and the experienced group having 4–6 years of training experience. All participants attended training sessions five times a week and were preparing for competitions, training CrossFit at a competitive level. Both groups were evaluated for skinfold thickness and body fat percentage using appropriate measurement techniques, while functional movements were assessed separately using the Functional Movement Screen (FMS) Kit system and protocol. The results indicated that the experienced group demonstrated significantly higher overall FMS scores ($U = 71.5$, $p < 0.001$, $r = 0.67$), suggesting better functional movement patterns and potentially lower injury risk. They also exhibited higher body density and lower body fat percentages ($U = 126$, $p < 0.001$, $r = 0.51$) compared to the beginner group, which had higher skinfold thickness measurements in the breast, abdominal, and thigh areas. The findings of the study suggest that with increased experience in CrossFit training, athletes tend to have lower body fat, especially in the lower body, and exhibit improved functional movement quality. These improvements in movement efficiency potentially decrease the risk of injury, highlighting the benefits of long-term participation in high-intensity CrossFit training.

Key words: functional training, functional movement screen, body fat, injury risk

Introduction

The internet has played a significant role of CrossFit in making this program widely accessible, which has resulted in increased interest from individuals of all fitness levels (Kuhn, 2013). While the benefits of CrossFit are multifaceted and have been studied extensively, the safety of this high-intensity training method continues to be a subject of debate (Herz et al., 2015; Kuhn, 2013). Nevertheless, many studies have shown that CrossFit can lead to improved physical fitness, body composition, and overall health (Ballesta-García et al., 2019; Hamdouni et al., 2022; Moghimi Sarani, 2020). It is important for anyone looking to start CrossFit training to consider their physical condition and aptitude, as well as the need for proper nutrition, regularity, varied physical training, and adequate recover (Dawson, 2017; Kuhn, 2013). Overall, CrossFit has become a popular and effective training method for individuals looking to improve their physical fitness and functional capacity. CrossFit is a high-intensity training methodology that combines elements of weightlifting, gymnastics, and cardiovascular exercises to enhance overall fitness. It focuses on functional movements that mimic everyday activities, such as squatting, lifting, pushing, and pulling, which involve multiple muscle groups and improve functional strength and efficiency (Kuhn, 2013). CrossFit include daily Workouts of the Day (WODs), consisting of a warm-up, skill or strength work, and a main workout that can be a timed challenge, a set number of repetitions, or a combination of exercises. Exercises are scalable, allowing individuals of different fitness levels to participate and benchmark workouts are periodically repeated to measure progress (Leitão et al., 2021). CrossFit has been associated with an increased risk of injury due to its high-intensity nature and focus on functional movements, as the high intensity and variable pace can potentially lead to incorrect exercise technique and affect movement quality. Research has shown that injury rates in CrossFit are relatively high, especially for newcomers or those who have not been physically active for a while (Smith et al., 2013). However, studies also suggest that injury rates in CrossFit are similar to those in other high-intensity sports, such as running, weightlifting, and gymnastics. The Functional Movement Screen (FMS) can be used as a pre-participation tool to detect biomechanical anomalies in athletes caused by either a previous injury or abnormal movement patterns from training-intensity sports such as Olympic weightlifting and powerlifting (Weisenthal et al., 2014). Injuries in CrossFit often involve the shoulder, back, and knee, and may result from poor technique, overtraining, or lack of proper warm-up and cool-down routines (Smith et al., 2013). However, injury risk can be minimized by working with a qualified coach who emphasizes proper technique, gradually increasing the intensity and volume of training, and taking adequate rest and recovery time between workouts (Kaczorowska et al., 2020; Klimek et al., 2018). It is also important for individuals to listen to their bodies and avoid pushing themselves beyond their limits, as this can increase the risk of injury. CrossFit can be a safe and effective way to improve fitness and functional performance, but it is crucial to approach training with caution and respect for one's physical limitations (Herz et al., 2015).

The Functional Movement Screen (FMS) can be used as a pre-participation tool to detect biomechanical anomalies in athletes caused by either a previous injury or abnormal movement patterns from training (Cook et al., 2006a; Kiesel et al., 2007; Schneiders et al., 2011). The FMS can also be used to predict injury by finding a relationship between a low FMS score and the occurrence of injury. CrossFit athletes can be assessed using FMS to detect any movement abnormalities and asymmetries. CrossFit produces a clear symmetry in some fundamental movements compared to weightlifting and bodybuilding (Tafuri et al., 2016). Functional movement and anthropometric measurements, including FMS score, can predict athletic performance in different disciplines. Athletes with higher FMS scores and lower body fat levels performed better in the 100-meter swim (Bond et al.,

2015). The FMS is an effective tool in determining the functional level of athletes at different levels of preparation in different disciplines (Bond et al., 2015). The study by Klimek et al. (2018) shows that CrossFit conducted in the right way does not affect the risk of injury as one might expect. More than 1,500 athletes at various levels of experience took part in the study, which gives great hope for the usefulness of CrossFit training.

Functional movement screening (FMS) has become an essential tool for assessing movement patterns, identifying biomechanical anomalies, and predicting injury risk in athletes. However, several factors can influence the FMS scores of an individual, including their age, gender, and body fat levels. Studies have shown that body fat levels and FMS scores can be associated with athletic performance. Bond et al. (Bond et al., 2015) found a high correlation between FMS score, body fat levels, and swimming speed in competitive swimmers of 100-meter swim. Similarly, a study by Campa et al. (2019) revealed that body fat levels had a negative impact on FMS scores in. Age can also be a factor in FMS scores. Wright & Chesterton (2018) suggested that testing young athletes aged 8–18 years for FMS may be unreliable due to the effects of puberty. However, Kuzuhara et al. (2018) found no correlation between age and FMS scores in mini-basketball players. Gender can also play a role in FMS scores. A study by Tafuri et al. (2016) compared CrossFit athletes' FMS scores to weightlifters and bodybuilders and found a high level of congruence in performance on bilateral tests. However, the study revealed that active straight leg lifting showed a lack of symmetry between the genders, with female athletes performing worse than male athletes. Additionally, Magyari et al. (Magyari 2017) found that female athletes had lower FMS scores than male athletes, indicating that gender may play a role in FMS scores. In conclusion, while FMS has proven to be an effective tool in assessing an athlete's movement patterns and injury risk, factors such as body fat levels, age, and gender should be taken into consideration when interpreting FMS scores. More research is needed to further explore the impact of these factors on FMS scores and develop appropriate protocols for using FMS in different age and gender groups of athletes.

Drawing on the evidence presented, CrossFit emerges as an effective way to improve physical fitness and functional capacity. However, due to its high intensity, there is a risk of injury. To reduce this risk, it is important to train carefully and be aware of one's physical limits. Using the Functional Movement Screen (FMS) can help assess an individual's readiness for CrossFit by identifying movement problems and predicting injury risk. With tools like FMS and guidance from experienced coaches, people can safely and effectively enhance their fitness through CrossFit. The main goal of this study is to examine the effects of CrossFit training on body composition and movement quality in athletes at different experience levels. Specifically, the study aims to:

1. Compare body fat percentage and skinfold measurements between novice and experienced CrossFit athletes.
2. Assess functional movement quality using the FMS in both groups.
3. Investigate the relationship between CrossFit experience and injury risk based on FMS scores.

Based on the literature and preliminary observations, this study hypothesizes that experienced CrossFit athletes will have lower body fat percentages, lower skinfold measurements, higher FMS scores indicating better movement quality and lower injury risk, and that there will be a negative correlation between years of CrossFit training and body fat percentage, as well as a positive correlation between training experience and FMS scores.

Material and Methods

Ethics statement

The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the Bioethics Committee of the Medical Chamber (Resolution No. 316 of 1 October 2020).

We involved fifty active male CrossFit athletes, divided into beginner and experienced groups, in our study. The athletes in the beginning group (n = 25, mean age 24.8 ±5.2 years) had no more than 2 years of training experience, while the athletes in the experienced group (n = 25, mean age 25.1 ±4.9 years) had between 4–6 years of training experience. All participants attended training sessions five times a week and were preparing for competitions, training CrossFit at a competitive level.

Body composition and movements parameter analysis

Fold Meter Electronic Body Mass Measurement Instrument.

We measured body fat and lean body mass levels using a device that determined body fat percentage and lean body mass levels by first assessing skin-fat fold measurements of the upper, middle, and lower body (chest, abdominal muscles, quadriceps). Before taking measurements, we entered body weight in kilograms, body height in centimeters, and age into the device. We measured skinfold thickness at each site three times and calculated the arithmetic mean. We calculated body fat mass using logarithmic indices and took measurements using a skinfold meter. Error in this method were estimated to be between 3–9% (Westerterp & Skowrońska, 2007). We incorporated these measurements into “Table 1” in the Results section, appearing in the second, third, and fourth positions, respectively.

Tanita Body Composition Analyzer

We assessed body composition using the TBF-310 foot-to-foot model, which provided a printout of measured impedance and calculated FM and FFM. Subjects were barefoot and in underwear during the assessment (Domingos et al., 2019). From the findings obtained through the electrical bioimpedance analyser, the percentage measurement of adipose tissue was employed. It was incorporated into “Table 1” within the Results section, appearing in the final position under the designation “Body fat [%]”.

Functional Movement Screen test.

We conducted the study using the FMS Kit system and followed the FMS test protocol. Each participant performed three attempts of each of the seven tests according to the recommended instructions. The tests consisted of deep squat, hurdle step, in-line lunge, shoulder mobility assessment, active straight leg rise, trunk stability push up and rotational stability (Cook et al., 2006b, 2006a). Each of the seven tests is scored separately on a scale of 0 to 3 points. The maximum score for all tests is 21 points. Interpreting the results: a range of 18 to 21 indicates the subject’s normal movement patterns and adequate motor control and proper ranges of mobility and stability in the joints. A range of 15 to 17 points indicates the appearance of functional asymmetry and compensation (Cook, 2010). In the analysis, the overall Functional Movement Screen (FMS) score was employed for comparison between groups. The individual conducting the FMS test is certified and has completed the original and patented FMS diagnostic course.

Reliability of Measurements

To ensure the consistency of our FMS (Functional Movement Screen) assessments, we included both intrarater and interrater reliability estimates. The intrarater reliability (ICC = 0.85) was based on repeated assessments by the same evaluator over time, confirming consistent scoring within the same rater (Cook et al., 2006a). The interrater reliability (ICC = 0.75) was derived from assessments by different evaluators, ensuring that different raters provided consistent scores for the same athletes (Cook et al., 2006b). Additionally, the reliability for skinfold measurements was reported as ICC = 0.90 in previous studies (Westerterp & Skowrońska, 2007). Furthermore, the Tanita TBF-310 body composition analyzer demonstrated a reliability index of ICC = 0.92, ensuring consistent body fat percentage measurements (Domingos et al., 2019). These reliability estimates affirm the robustness and consistency of our assessment methods, providing confidence in the accuracy and reproducibility of our measurements.

Statistical Analysis

We used the Mann-Whitney U test to analyze the significance of differences between groups. We analyzed the collected data using StatsCloud software (https://statscloud.app/beta/). We determined the size of the intervention group using the GPower 3.1.9.2 program. With a total sample size of 50 persons in each of the 2 groups, we detected an effect size (0.71) with 80% power and a 5% significance level.

Results

We found that the experienced stage group had higher total scores than the beginning stage group. A Mann-Whitney U test revealed this difference as statistically significant ($U = 71.5$, $p < 0.001$, $r = 0.67$). Our analysis also demonstrated that all body composition parameters were statistically significantly different between the study groups.

The beginning stage group had statistically significantly higher scores than the experienced stage group for breast fold ($U = 198$, $p = 0.025$, $r = 0.32$), abdominal fold ($U = 157$, $p = 0.002$, $r = 0.43$), thigh fold ($U = 165.5$, $p = 0.004$, $r = 0.41$), and body fat ($U = 126$, $p < 0.001$, $r = 0.51$).

We observed that the experienced stage group had higher scores for body density than the beginning stage group ($U = 157.5$, $p < 0.001$, $r = 0.48$).

Table 1. Table of results for statistical significance of differences in individual parameters between experienced vs beginners group

Group			Test statistics		
Outcome	Predictor	Group	U	z	p
Total score	Stage	Beginners Experienced	71.5	–4.765	< 0.001
Chest fold (mm)	Stage	Beginners Experienced	198.0	–2.249	0.025
Abdominal fold (mm)	Stage	Beginners Experienced	157.0	–3.025	0.002
Thigh fold (mm)	Stage	Beginners Experienced	165.5	–2.866	0.004
Body density (g/cm3)	Stage	Beginners Experienced	157.5	–3.399	< 0.001
Body fat (%)	Stage	Beginners Experienced	126.0	–3.62	< 0.001

Discussion

The study investigated differences in physical fitness and body composition between beginning and experienced stage male CrossFit athletes. Our results indicate significant statistical differences between the two groups for several measures. The beginning stage group had significantly higher scores for breast fold, abdominal fold, and thigh fold compared to the experienced stage group, suggesting more body fat in these areas. This difference may be due to the varying levels of training experience between the beginner and experienced athletes. Conversely, the experienced stage group had significantly higher scores for body density and total FMS score, suggesting a lower body fat percentage and better functional movement patterns. This could result from more intensive and specific training to improve physical fitness and performance in the experienced stage group.

FMS, designed to assess functional movements and injury risk, is crucial in CrossFit diagnostics. CrossFit's impact on biomechanics varies with age and fitness levels, making it essential to assess its effects at different life stages. FMS requires selecting an age-appropriate group; scores may be unreliable in adolescents (Wright & Chesterton, 2018). Montalvo et al. (2017) found higher FMS scores in experienced CrossFit athletes compared to novices, consistent with our study. Similarly, Davis et al. (Davis et al., 2020) found a positive association between higher FMS scores and better physical performance in soldiers. Moore et al. (2019) noted mixed results on FMS scores and injury risk, suggesting higher FMS scores might indicate lower injury risk, though further research is needed.

Comparing the results with Perna et al. (2018) have different research designs and aims. The above research is a cross-sectional study comparing two groups of CrossFit athletes at a single point in time, while Perna et al. (2018) research is a pre-post trial evaluating the effects of different training interventions of CrossFit on body composition markers. Additionally, the measurements used in each result differ, with Methods in this article using skinfold thickness and body density measurements, while Perna et al. (2018) used DXA to measure body composition. Despite these differences, both results show that body composition can be significantly affected by different factors such as stage of training and type of high-intensity training. This suggests that individuals and trainers should consider these factors when designing and implementing training programs. Study of Smith et al. (2013) describe a study that aimed to investigate the effects of CrossFit training on cardiovascular risk factors in overweight men. The study compared two groups, the CrossFit group, and the control group. The CrossFit group showed significant improvements inter alia for weight, BMI, body fat percentage compared to the control group. However, no significant differences were observed between the two groups for waist, hip and thigh circumferences, waist-hip ratio. Looking for similarities both studies involved comparing different groups, they differ in their specific focus and outcome measures. Above studies aimed to compare the body composition measures between two different groups of athletes, whereas Smith et al. (2013) focused on the effects of CrossFit training on cardiovascular risk factors in overweight men and provides a wider range of measures including body composition, physical fitness, and lipid profile. The results of the study Menargues-Ramirez et al. (2022) on anthropometric characteristics of CrossFit athletes suggest that having low fat mass and high muscle mass can benefit an athlete's performance in this sport. This finding is consistent with the notion that CrossFit involves a combination of strength and cardiovascular exercises and having a low body fat percentage and high muscle mass can help athletes perform well in both areas. Interestingly, the study (Menargues-Ramírez, 2022) found that the physical demands of lifting heavy loads in CrossFit resulted in athletes having anthropometric values similar to elite weightlifting athletes than in other sports. This highlights the importance of strength training in CrossFit, and how it can have a significant impact

on an athlete's body composition and performance. In comparison, both studies highlight the importance of body composition in athletic performance and how training can influence it. In the context of CrossFit, having a low body fat percentage and high muscle mass can be advantageous for athletes, while training can lead to changes in body composition over time.

Our findings reveal significant differences between beginning and experienced stage athletes, with the latter group exhibiting lower body fat percentages, better functional movement patterns, and higher FMS scores. These differences could be attributed to the advanced training and practice of experienced stage athletes. Furthermore, the relationship between FMS scores and injury risk remains inconclusive, warranting further investigation. Similarities between these studies and those by Smith et al. (2013) and Menargues-Ramirez et al. (2022) demonstrate the impact of CrossFit training on various aspects of physical fitness and body composition. CrossFit athletes may benefit from low body fat percentages and high muscle mass, as these factors can positively influence performance in both strength and cardiovascular exercises. Overall, these findings underscore the importance of considering factors such as training stage and intensity when designing and implementing training programs for CrossFit athletes. A comprehensive understanding of body composition and physical fitness in relation to performance can help trainers and athletes optimize their training approach and achieve better results.

This study is novel in that it provides a detailed analysis of the long-term impact of CrossFit training on somatic parameters and functional movement quality. Our findings highlight the significant differences in body composition and functional movement between novice and experienced CrossFit athletes, emphasizing the importance of advanced training. However, this study has several limitations that should be considered when interpreting the findings. FMS relies heavily on the subjective judgment of examiners, which can introduce variability in scoring due to individual interpretation differences. Additionally, the 0–3 scoring system used in FMS lacks granularity, making it less effective at distinguishing subtle differences in performance and movement quality among athletes of varying skill levels. Furthermore, the reliance on skinfold measurements for assessing body composition, although generally reliable, is also subject to the technique and experience of the evaluator, which can introduce potential errors. Despite high interrater reliability reported for these measurements (ICC = 0.90) (Westerterp & Skowrońska, 2007), subjective error remains a concern. These limitations suggest that while our findings offer valuable insights into the differences between beginning and experienced CrossFit athletes, they should be interpreted with caution. Addressing these issues in future research will help provide more definitive conclusions and better support the development of effective training programs for CrossFit athletes.

Conclusions

This study enhances our understanding of the differences in body composition and physical fitness between novice and experienced CrossFit athletes. Our findings demonstrate that experienced CrossFit athletes have lower body fat percentages, better functional movement patterns, and higher FMS scores compared to novice athletes. These differences can be attributed to the advanced training and practice of experienced athletes, highlighting the significant impact of CrossFit training on physical fitness and body composition. These results underscore the importance of personalized CrossFit training programs, taking into consideration the athlete's training stage and intensity. By focusing on these factors, trainers can optimize training approaches to improve performance and reduce injury risks. This study contributes valuable insights that can aid in the development of more effective and individualized training regimens for CrossFit athletes.

Supplementary Materials

Table 2. Results of the FMSTM test of athletes at the beginning stage

Number of athletes	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Total Score
Athlete 1	3	2	2	3	2	3	2	17
Athlete 2	3	2	3	2	2	3	2	17
Athlete 3	2	2	3	0	2	3	2	14
Athlete 4	2	2	3	2	2	3	2	16
Athlete 5	3	2	2	3	2	3	2	17
Athlete 6	3	2	3	3	3	3	2	19
Athlete 7	2	2	3	3	3	3	2	18
Athlete 8	2	2	3	0	2	3	3	15
Athlete 9	2	2	3	0	2	3	2	14
Athlete 10	2	2	2	2	1	3	2	14
Athlete 11	2	2	3	3	2	3	2	17
Athlete 12	2	2	2	3	2	0	2	13
Athlete 13	2	3	3	2	2	3	2	17
Athlete 14	1	2	2	3	2	3	2	15
Athlete 15	3	2	3	3	2	3	2	18
Athlete 16	2	2	2	2	2	2	1	13
Athlete 17	3	2	3	3	3	3	2	19
Athlete 18	3	2	2	3	2	3	2	17
Athlete 19	3	2	2	2	2	2	2	15
Athlete 20	3	2	2	3	2	3	2	17
Athlete 21	3	3	3	3	2	3	2	19
Athlete 22	2	2	3	3	2	3	2	17
Athlete 23	2	3	2	2	2	3	2	16
Athlete 24	3	2	3	1	2	2	2	15
Athlete 25	2	2	2	3	2	2	2	15

Table 3. Results of the FMSTM test of athletes at the expierienced stage

Number of Athletes	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Total Score
Athlete 1	3	3	3	3	3	3	2	20
Athlete 2	3	2	3	3	2	3	2	18
Athlete 3	3	2	3	3	2	3	2	18
Athlete 4	3	3	3	2	2	3	2	18
Athlete 5	3	2	3	3	2	3	2	18
Athlete 6	3	3	3	3	3	3	2	20
Athlete 7	3	2	3	2	3	3	2	18
Athlete 8	3	3	3	2	3	3	2	19
Athlete 9	3	2	3	3	2	3	2	18
Athlete 10	3	2	3	3	2	3	2	18
Athlete 11	3	2	3	3	2	3	2	18
Athlete 12	3	2	3	3	3	3	2	19
Athlete 13	3	3	3	3	3	3	2	20
Athlete 14	3	3	3	3	2	3	2	19
Athlete 15	3	3	3	3	3	3	3	21
Athlete 16	3	2	3	2	2	3	1	17
Athlete 17	3	2	3	3	3	3	2	19

Number of Athletes	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Total Score
Athlete 18	3	3	3	3	2	3	2	19
Athlete 19	3	3	3	2	3	3	2	19
Athlete 20	3	3	2	3	2	3	2	18
Athlete 21	3	2	3	3	3	3	2	19
Athlete 22	3	2	3	3	3	3	2	19
Athlete 23	3	2	2	3	3	3	2	18
Athlete 24	3	3	3	2	3	3	2	19
Athlete 25	3	2	3	2	2	3	2	17

Table 4. Results of the skinfold measurements and body fat of athletes at the beginning stage

Number of Athletes	(mm) Thoracic fold	(mm) Abdominal fold	(mm) Thigh fold	(g/cm3) Body density	(%) Body fat
Athlete 1	12	19	12	1,07	12.79
Athlete 2	16	27	14	1,06	16.41
Athlete 3	9	18	15	1,07	12.07
Athlete 4	17	38	35	1,04	25.13
Athlete 5	19	22	24	1,05	18.47
Athlete 6	8	23	21	1,06	15.3
Athlete 7	8	13	19	1,07	11.72
Athlete 8	6	28	27	1,05	17.76
Athlete 9	8	18	11	1,07	10.89
Athlete 10	9	2	16	1,08	8.24
Athlete 11	11	23	11	1,06	13.82
Athlete 12	8	22	25	1,06	16.09
Athlete 13	8	24	16	1,06	14.22
Athlete 14	10	14	22	1,06	13,16
Athlete 15	14	20	12	1,06	13.37
Athlete 16	10	18	14	1,07	12.58
Athlete 17	9	18	20	1,06	13.95
Athlete 18	7	16	12	1,07	10.02
Athlete 19	6	11	12	1,07	9.25
Athlete 20	8	27	18	1,06	15.46
Athlete 21	9	18	15	1,07	12.17
Athlete 22	11	11	15	1,07	10.99
Athlete 23	10	19	18	1,06	13.64
Athlete 24	9	15	20	1,06	13.44
Athlete 25	12	25	21	1,05	17.09

Table 5. Results of the skinfold measurements and body fat of athletes at the experienced stage

Number of Athletes	(mm) Thoracic fold	(mm) Abdominal fold	(mm) Thigh fold	(g/cm3) Body density	(%) Body fat
Athlete 1	11	9	11	1.07	9.19
Athlete 2	8	25	12	1.06	13.51
Athlete 3	5	17	17	1.07	11.24
Athlete 4	4	16	14	1.07	10.04
Athlete 5	8	15	20	1.07	12.45
Athlete 6	7	14	17	1.07	11.17
Athlete 7	9	19	9	1.07	11.29

Number of Athletes	(mm) Thoracic fold	(mm) Abdominal fold	(mm) Thigh fold	(g/cm3) Body density	(%) Body fat
Athlete 8	7	12	18	1.07	11.29
Athlete 9	4	8	3	1.08	5.11
Athlete 10	7	12	15	1.07	10.14
Athlete 11	6	13	9	1.08	8.83
Athlete 12	8	12	12	1.07	9.68
Athlete 13	10	16	11	1.07	11.29
Athlete 14	9	17	12	1.07	11.17
Athlete 15	9	18	17	1.06	13.03
Athlete 16	8	15	10	1.07	10.27
Athlete 17	7	14	15	1.07	11.32
Athlete 18	11	21	11	1.07	12.86
Athlete 19	6	17	17	1.07	11.72
Athlete 20	9	18	18	1.06	13
Athlete 21	9	16	12	1.07	10.99
Athlete 22	12	11	11	1.07	10.25
Athlete 23	10	13	15	1.07	11.17
Athlete 24	8	13	17	1.07	11.47
Athlete 25	9	15	9	1.07	10.16

References

Ballesta-García, I., Martínez-González-Moro, I., Rubio-Arias, J., & Carrasco-Poyatos, M. (2019). High-intensity interval circuit training versus moderate-intensity continuous training on functional ability and body mass index in middle-aged and older women: A randomized controlled trial. *International Journal of Environmental Research and Public Health*, *16*(21), Article 4205. https://doi.org/10.3390/ijerph16214205

Bond, D., Goodson, L., Oxford, S. W., Nevill, A. M., & Duncan, M. J. (2015). The association between anthropometric variables, functional movement screen scores and 100 m freestyle swimming performance in youth swimmers. *Sports*, *3*(1), 1–11. https://doi.org/10.3390/sports3010001

Campa, F., Piras, A., Raffi, M., & Toselli, S. (2019). Functional movement patterns and body composition of high-level volleyball, soccer, and rugby players. *Journal of Sport Rehabilitation*, *28*(7), 740–745. https://doi.org/10.1123/jsr.2018-0087

Cook, G., Burton, L., & Hoogenboom, B. (2006a). Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. *North American Journal of Sports Physical Therapy : NAJSPT*, *1*(2), 62–72.

Cook, G., Burton, L., & Hoogenboom, B. (2006b). Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. *North American Journal of Sports Physical Therapy : NAJSPT*, *1*(3), 132–139.

Cook, G. (2010). *Movement: Functional movement systems: Screening, assessment and corrective strategies* (2nd ed.). On Target Publications.

Davis, J. D., Orr, R., Knapik, J. J., & Harris, D. (2020). Functional Movement Screen (FMS™) Scores and Demographics of US Army Pre-Ranger Candidates. *Military Medicine*, *185*(5–6), e718–e724. https://doi.org/10.1093/milmed/usz373

Dawson, M. C. (2017). CrossFit: Fitness cult or reinventive institution? *International Review for the Sociology of Sport*, *52*(3), 361–379. https://doi.org/10.1177/1012690215591793

Domingos, C., Matias, C. N., Cyrino, E. S., Sardinha, L. B., & Silva, A. M. (2019). The usefulness of Tanita TBF-310 for body composition assessment in Judo athletes using a four-compartment molecular model as the reference method. *Revista Da Associacao Medica Brasileira*, *65*(10), 1283–1290 https://doi.org/10.1590/1806-9282.65.10.1283

Hamdouni, H., Kliszczewicz, B., Zouhal, H., Rhibi, F., Ben Salah, F. Z., & Ben Abderrahman, A. (2022). Effect of three fitness programs on strength, speed, flexibility and muscle power on sedentary subjects. *Journal of Sports Medicine and Physical Fitness*, *62*(1), 132–139. https://doi.org/10.23736/S0022-4707.21.12086-9

Herz, J. C., Morais, D. G., & Todd, J. (2015). Learning to Breathe Fire: The Rise of CrossFit and the Primal Future of Fitness. *Sport Management Review*, *18*(4), 491–493. https://doi.org/10.1016/j.smr.2014.11.007

Kaczorowska, A., Noworyta, K., Mroczek, A., & Lepsy, E. (2020). Effect of the mobilityWOD training program on functional movement patterns related to the risk of injury in crossfit practitioners. *Acta Gymnica*, *50*(1), 1–10. https://doi.org/10.5507/ag.2020.002

Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can Serious Injury in Professional Football be Predicted by a Preseason Functional Movement Screen? *North American Journal of Sports Physical Therapy : NAJSPT*, *2*(3), 147–158.

Klimek, C., Ashbeck, C., Brook, A. J., & Durall, C. (2018). Are injuries more common with CrossFit training than other forms of exercise? *Journal of Sport Rehabilitation*, *27*(3), 295–299. https://doi.org/10.1123/jsr.2016-0040

Kuhn, S. (2013). *The culture of CrossFit: A lifestyle prescription for optimal health and fitness* (Senior thesis, Illinois State University). Illinois State University. https://ir.library.illinoisstate.edu/sta/1

Kuzuhara, K., Shibata, M., Iguchi, J., & Uchida, R. (2018). Functional Movements in Japanese Mini-Basketball Players. *Journal of Human Kinetics*, *61*(1), 135–142. https://doi.org/10.1515/hukin-2017-0128

Leitão, L., Dias, M., Campos, Y., Vieira, J. G., Sant'ana, L., Telles, L. G., Tavares, C., Mazini, M., Novaes, J., & Vianna, J. (2021). Physical and physiological predictors of fran crossfit® wod athlete's performance. *International Journal of Environmental Research and Public Health*, *18*(8), Article 4070. https://doi.org/10.3390/ijerph18084070

Magyari, N., Szakács, V., Bartha, C., Szilágyi, B., Galamb, K., Magyar, M. O., Hortobágyi, T., Kiss, R. M., Tihanyi, J., & Négyesi, J. (2017). Gender may have an influence on the relationship between Functional Movement Screen scores and gait parameters in elite junior athletes – A pilot study. *Physiology International*, *104*(3), 231–242. https://doi.org/10.1556/2060.104.2017.3.1

Menargues-Ramírez, R., Sospedra, I., Holway, F., Hurtado-Sánchez, J. A., & Martínez-Sanz, J. M. (2022). Evaluation of body composition in CrossFit® athletes and the relation with their results in official training. *International Journal of Environmental Research and Public Health, 19*(17), Article 11003. https://doi.org/10.3390/ijerph191711003

Moghimi Sarani, A. (2020). CrossFit training improves blood lipid profile in overweight men: A randomized controlled trial. *Journal of Physical Activity and Hormones* , *4*(1), 17–28.

Montalvo, A. M., Shaefer, H., Rodriguez, B., Li, T., Epnere, K., & Myer, G. D. (2017). Retrospective injury epidemiology and risk factors for injury in CrossFit. *Journal of Sports Science and Medicine*, *16*(1), 53–59.

Moore, E., Chalmers, S., Milanese, S., & Fuller, J. T. (2019). Factors Influencing the Relationship Between the Functional Movement Screen and Injury Risk in Sporting Populations: A Systematic Review and Meta-analysis. In *Sports Medicine, 49*(9), 1449–1463. https://doi.org/10.1007/s40279-019-01126-5

Perna, S., Bologna, C., Agosti, I. D., & Rondanelli, M. (2018). High intensity crossfit training compared to high intensity swimming: A pre-post trial to assess the impact on body composition, muscle strength and resting energy expenditure. *Asian Journal of Sports Medicine*, *9*(1), Article e13843– https://doi.org/10.5812/asjsm.13843

Schneiders, A. G., Davidsson, A., Hörman, E., & Sullivan, S. J. (2011). Functional movement screen normative values in a young, active population. *International Journal of Sports Physical Therapy*, *6*(2), 75–82.

Smith, M. M., Sommer, A. J., Starkoff, B. E., & Devor, S. T. (2013). Crossfit-based high-intensity power training improves maximal aerobic fitness and body composition. In *Journal of Strength and Conditioning Research, 27*(11), 3159–3172. https://doi.org/10.1519/JSC.0b013e318289e59f

Tafuri, S., Notarnicola, A., Monno, A., Ferretti, F., & Moretti, B. (2016). Crossfit athletes exhibit high symmetry of fundamental movement patterns. A cross-sectional study. *Muscles, Ligaments and Tendons Journal*, *6*(1), 157–160. https://doi.org/10.11138/mltj/2016.6.1.157

Weisenthal, B. M., Beck, C. A., Maloney, M. D., DeHaven, K. E., & Giordano, B. D. (2014). Injury rate and patterns among crossfit athletes. *Orthopaedic Journal of Sports Medicine*, *2*(4), Article 2325967114531177. https://doi.org/10.1177/2325967114531177

Westerterp K. R., & Skowrońska U. (2007). *Skład ciała i jego pomiary, red. Sobotka L., Podstawy żywienia klinicznego: Vol. PZWL*.

Wright, M. D., & Chesterton, P. (2018). Functional Movement ScreenTM total score does not present a gestalt measure of movement quality in youth athletes. *Journal of Sports Sciences, 36(22), 2521–2527. https://doi.org/10.1080/02640414.2018.1465724*

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IS WRESTLING A PROMISING SPORT FOR YOUNGSTERS FROM DEPRIVED REGIONS?

Celal Taşkıran[A, B, C, D]

Physical Education Department, Faculty of Sport Sciences, Hitit University, Corum, Turkey
e-mail: celaltaskiran@hitit.edu.tr
ORCID: 0000-0003-4228-2678

Mehmet Kutlu[A, B, C ,D]

Physical Education Department, Faculty of Sport Sciences, Hitit University, Corum, Turkey
ORCID: 0000-0002-2481-010X

Erkan Demirkan[B, C]

Coaching Department, Faculty of Sport Sciences, Hitit University, Corum, Turkey
ORCID: 0000-0002-6243-8062

Turgut Yıldırım[C, D]

Coaching Department, Faculty of Sport Sciences, Hitit University, Corum, Turkey
ORCID: 0000-0003-1391-6942

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

Abstract This study aimed at exploring the social factors in lead young wrestlers with disadvantaged background and from deprived regions to take up wrestling. Utilizing a cross-sectional survey design, the research explores demographics, socio-economic status, and the motivators behind wrestling involvement among 129 participants aged 9 to 16. Purposefully selecting regions with limited wrestling activity, the study is part of a special project. Conducted incentive camping period in Antalya study reveal that key motivators to wrestlers include Physical Education Teachers (PET) (22%), friends (19%), siblings (15%), fathers (12%) and others (14%). Although, there were 70% of participants who have some idols from countrywide, it was found that they have lack of idols in the regions of our participant group. Despite wrestlers have some disadvantages in social status such as the lack of wrestling authority in family members, camping affected them positively and encouraged them in wrestling career. Prospective wrestlers had declared that they come from low-income families underlining the socio-economic difficulties. It is thought that situations such as conducting the study in a seaside camp in a 5-star hotel, recognizing idol athletes increase the children's interest in wrestling and will have a positive effect on their future sports life despite their disadvantaged backgrounds.

Key words: candidate wrestlers, motivators, demographic features, deprived regions

Introduction

Wrestling is a popular high-intensity combat sport that requires a combination of physical strength, endurance, and technical skills. While wrestling has gained increasing attention worldwide, it remains inaccessible to many young individuals from disadvantaged backgrounds and deprived regions. Starting age and years of experience are crucial factors that can affect an individual's performance in wrestling. In a recent study it is suggested that individuals begin wrestling at early ages to ensure maximum development of the necessary physical and technical skills. Additionally, there is a significant correlation between years of experience and peak performance age, suggesting that the more experience one has, the higher their peak performance age may be. Thus, adolescents should start wrestling at the age of 10 and for the peak performance, they will need around 14 years of training (Baić et al., 2014). Additionally, wrestling is not considered a safe sport for children by most families as it is often combined with a high degree of muscle damage due to demanding movements through training and technique, such as concentric and eccentric muscle use with high levels of applied force (Ratel et al., 2006). For this reason, most families from upper segment of the society do not want their children to take up wrestling as a starting point for sports even though they have enough opportunities and access. The lack of accessibility to wrestling for young individuals from disadvantaged backgrounds and deprived regions highlights the need to explore the social, educational, and personal factors that lead them to pursue the sport. Although the sport of wrestling is gaining increasing attention around the world, it is still inaccessible to many young individuals from disadvantaged backgrounds and deprived areas. Understanding these factors can inform initiatives aimed at increasing access to wrestling and improving it. In addition to psychological factors such as character traits and aggressive impulses, socio-cultural factors and local communities play a critical role in the adoption of or rejection of combat sports by the society and families, particularly in directing children to sports. Regarding this context, combat sports such as boxing, wrestling, MMA etc. emerged and became more common in the process of institutionalizing the sport. In the social analysis of such events, historical and cultural background of the communities, public interest and existence of civilized social projections aimed at raising physically superior generations, self-protecting and mitigating urban violence on the streets can be listed as crucial political, social, and cultural factors in the understanding of combat sports. Moreover, the use of capitalist logic in combat sports arts predicted the commercialization of civilized violence. This process become more prevalent with the introduction of these combat sports practices ("body to body fight") into sports arenas, institutionalized by the upper class as a means of civilization. (Atkinson, 2002; Mathisen et al., 2022; Seward, 1987; Torrebadella-Flix & Gutiérrez-García, 2022). In view of this context, although wrestling is regarded as a traditional and popular sport in Turkey, yet there is a disparity between the regions of Turkey in the engagement of wrestling. In Turkey, wrestling has traditionally been more popular in the western and central regions, and opportunities for wrestling in the eastern regions are limited. In response to this situation, the Turkish Wrestling Federation (TWF) has launched a project aimed at encouraging and supporting young candidates from the eastern regions to take up wrestling. This paper presents the results of a cross-sectional survey of 129 young candidate wrestlers from relatively disadvantaged regions of Turkey, focusing on the social, educational, and personal factors that motivate them to take up wrestling. The findings of this study contribute to our understanding of the role of socio-economic status, family, peers, and coaches in shaping young wrestlers' motivations and aspirations. Despite its physical demands and technical requirements, wrestling can be an immensely rewarding sport for young individuals. However, its inaccessibility to those from disadvantaged backgrounds and deprived regions is a pressing issue that deserves attention. In this context disadvantaged backgrounds operationally defined as rural

areas, low-income families, parents with low educational status, parents with low prestigious jobs or unemployed, wrestling is unpopular in the regions (eastern and south-eastern Anatolia), ethnically diverse population groups, and scarce wrestling champions as a role model. In addition, the common perception of wrestling as unsafe for children dissuades families from enrolling their children in the sport, particularly those from the upper segments of society. To address these issues, it is important to explore the factors that motivate young individuals from disadvantaged backgrounds to take up wrestling, and the educational and personal factors that contribute to their success in the sport. Such an understanding can help to promote greater accessibility to the sport and encourage more young individuals from diverse backgrounds to pursue their passion for wrestling. To fight this gap, TWF started a project in 2021 to help increasing the engagement of wrestling amongst the youngsters from the East and Southeastern regions of Turkey. With this regard the present study was carried out in cooperation with TWF to explore young wrestlers' motivation to take up wrestling as well as their socio-economical background. To achieve this overarching aim, the study addressed the following research questions:

1. What are the demographics of candidate wrestlers?
2. What is the socio-economic status (SES) of candidate wrestlers?
3. What are the factors motivating candidate wrestlers to take up wrestling?

In line with this research questions, we hypothesized that motivation to take up wrestling in candidate wrestlers from deprived regions of Turkey is associated with (a) socio-economic status, (b) supporting figures in family or social network, and (c) presence of idol wrestlers. Thus, the following research hypotheses were set and tested:

H1: Taking up wrestling is associated with the socio-economic status of the candidate wrestlers.

H2: Taking up wrestling is associated with the presence of supporting figures in family or social network of the candidate wrestlers.

H3: Taking up wrestling is associated with the presence of idol wrestlers.

Material and Methods

A cross-sectional survey design (Connelly, 2016) was employed as a methodological approach to examine young wrestlers' demographics, socio-economic status, as well as to determine the association between the antecedents of their wrestling motivation. The participating group of the study was determined by employing a purposive sampling technique (Creswell, 2012). The participants were 129 young wrestlers, aged from 9 to 16, who are living in relatively disadvantaged regions of Turkey, particularly in cities located in statistical regions TRA (Agrı, Kars, Igdır, Ardahan, Erzurum, Erzincan, Bayburt) TRB (Malatya, Elazığ, Bingöl, Tunceli, Van, Muş, Bitlis, Hakkari) and TRC (Gaziantep, Adıyaman, Kilis, Şanlıurfa, Mardin, Batman, Şırnak, Siirt). TRA, TRB, and TRC regions are provinces designated by the European Commission (Eurostat, 2024). Those regions were purposively selected since they are unproductive in terms of raising young and promising wrestlers compared to the other regions of Turkey. The present study is part of a project run by Turkish Wrestling Federation. The project aims to encourage and support youngsters from the regions in which wrestling is unpopular. In line with this project, the participants were surveyed during a camping period organized by Turkish Wrestling Federation in Antalya in June 2021. A written letter of approval of the ethical committee of Hitit University non-interventional studies was retrieved prior to study. The present study was approved by the Turkish Wrestling Federation. Since the participating candidate wrestlers were under 18, a written consent was retrieved from their parents or custodians.

The procedure

The participants were selected on a voluntary basis. Prior to data collection, they were informed by the researchers about potential benefits, risks, and survey questions of the study. In addition to surveying the participants, their physical characteristics (height, weight, BMI, percent fat) were measured. The coaches were also briefed about the study. After briefing, a total of 200 questionnaires were distributed to the participants. The next day, a total of 137 questionnaires were retrieved with a return rate of 80%. Prior to data analyses, the researchers scanned all the surveys and eliminated eight questionnaires since they were not filled out properly. After the elimination of the uncompleted or misconducted ones, a total of 129 eligible questionnaires were detected. However, in some of the questionnaires the participants did not prefer to answer all the questions. Thus, the analysis was run with the answered items. All statistical analyses were conducted using SPSS 25 to analyze survey data. Descriptive statistics such as mean, frequency, standard deviation, and min-max values were administered to summarize variables namely, demographics, socio-economic status indicator, and wrestling motivators.

Results

Firstly, based on our research aim, we analyzed students' answers from survey questions related to (1) young wrestlers' demographics and socio-economic status, (2) the presence of supporting figures in their families or social network, and (3) presence of wrestling idols, as well as other factors leading them to wrestling, including their interest in wrestling and other sports, their perception of and expectation from wrestling and other sports, where and how they do sport, what impedes them in sport, future profession, and family support and so forth with an open response alternative and a statement with one response alternatives were determined and illustrated in the following tables. As for the three hypotheses of the study, H1 was related to disadvantages of wrestling sport and candidate wrestlers mostly coming from lower SES families. H2 was related to the influence of supporting family members or social figures on wrestling motivation. H3 was associated with testing the impact of presence of idols in candidate wrestlers' lives.

Demographics results

In line with this, firstly, the descriptive statistics (Mean, SD, and percentage etc.) regarding the educational status were analyzed and the results were presented in Table 2. The educational level of the participants was examined, and the results illustrated that 87% were attending secondary school. With a closer look at the educational background of mothers of prepubescent wrestlers, 33% of them have not undergone formal education. 42% of them were graduated from primary schools. 23% of them were secondary or upper secondary graduates. None of their mothers have graduated from higher education. The 96% of the mothers were housewives who were unemployed or not included in workforce for more than one year. On the other hand, the 25% of fathers were unemployed or not included in workforce for more than one year. Table 1 illustrates the details about the demographics of the participants.

Table 1. The demographics of the young wrestling candidates (*N* = 129)

Variables	*n*	Mean	Min–Max	SD
Age in years	129	14,40	10,00–16,00	1,15
Height in meters	129	1,60	1,30–1,83	0,11
Weight in kg	129	55,30	32,00–108,00	15,3
BMI (kg / m^2)	129	20,87	16,00–36,00	3,80
School Grade	112	9,00	6,00–11,00	1,00
Sports Experience (year)	125	3,00	1,00– 8,00	1,57

The demographics presented in Table 1 also served as descriptors in the study.

The Socio-Economic Status of the young wrestlers

Table 2. The socio-economic status of the young wrestling candidates (*N* = 129)

Demographics	*n*	%	Mean	Min–Max	SD
School grade (secondary)	112	87	9,00	6–11	1,00
Number of Siblings	115	89	5,00	2–15	2,33
Family income (monthly)	110	85			
Minimum wage or below	82	75			
Average	27	24			
High	1	1			
Parental status	110	85	1,90	1–2	0,2
Married	104	95			
Divorced	6	5			
Mother's educational degree (total)	126	98	1,02	0–3	0,95
Not-in-formal	42	33			
Primary	54	43			
Secondary	16	13			
Upper-Secondary	14	11			
Higher Education	0	0			
Father's educational degree	126	98	1,90	0–4	1,10
Not-in-formal	17	14			
Primary	33	26			
Secondary	36	29			
Upper-Secondary	32	25			
Higher Education	8	6			
Mother employment status	129	100	0,10	0–1	0,21
Unemployed	123	95			
Employed	6	5			
Father employment status	123	95	0,80	0–1	0,43
Unemployed	30	23			
Employed	93	72			
Father's job	85	66			
Civil servant	14	11			
Worker	27	21			
Freelancer	33	26			
Other	11	9			
Region 1 (Eastern Turkey)	53	41			
Region 2 (Southeastern Turkey)	76	59			

Table 2 presents the socio-economic status of the young wrestling candidates based on various demographic and economic factors. The table includes information about school grade, number of siblings, family income, parental status, maternal and paternal educational degrees, as well as parental employment status and father's occupation. The data is summarized using counts, percentages, means, ranges (minimum to maximum values), and standard deviations (SD). 87% of the young wrestlers are in 9th grade, with a range from 6th to 11th grade. The average school grade is 9 (indicating the average class level). 89% of the candidates have an average of 5 siblings, ranging from 2 to 15. The standard deviation is 2.33, suggesting variability in the number of siblings. 85% of families earn minimum wage or below. 75% of families earn an average income. 24% of families have high income. Only 1 family reported an income above the high-income threshold. 95% of parents are married. 5% of parents are divorced. 33.3% of mothers have a non-education. 43% of mothers have a primary education. 13% of mothers have secondary education. 11% of mothers have upper secondary education. 98% of mothers have some form of formal education. 26% of fathers have a primary education. 29% of fathers have a secondary education. 25% of fathers have upper-secondary education. 6% of fathers have higher education. There are also 14% of fathers with non-education in the study. 95% of mothers are unemployed. 5% of mothers are employed. 23% of fathers are unemployed. 72% of fathers are employed. Among the fathers, 11% are civil servants, 21% are workers, 26% are freelancers, and 9% have other types of jobs. The table shows data from two regions, labeled as Region one and Region two. 41% young wrestling candidates are from region one whereas 59% are from region two. The candidates mostly come from families with lower to average income levels, with varying parental educational backgrounds and employment statuses. The educational degrees and employment statuses of both parents are quite diverse, and the father's job distribution highlights a variety of occupations among the candidates' fathers.

The findings of the study revealed that young wrestling candidates were coming from families form lower or average socio-economic status and wrestling was not popular sport in those deprived regions, which supports H1.

The Motivators of Wrestling

Five open-ended questions were used to determine the motivators of wrestling across young adolescents. The first two questions were used to determine the role of family in motivating adolescents for wrestling. These two questions were: *"Is there a wrestler in your family or relatives? If yes, who is it?"* and *"Is there anybody in your family or relatives who is engaged in other sports?".* The findings illustrated that out of 129 participants, 84 (65%) reported that there was nobody in their family or relatives who were engaged in wrestling in the past. Only 3 (2%) reported that their fathers were engaged in wrestling. Also, they reported there are no female figures involved in wrestling including mother or sisters in their families and relatives. On the other hand, nearly half of the participants (48%) also reported that there are some people in their families or relatives who are engaged in other sports. The third question was *"Who encouraged you to become a wrestler?"* 104 out of 129 participants (81%) reported that there is somebody who encouraged them to take up wrestling. Further analysis of the motivators illustrated that the motivators are respectively PE teacher (f:28, 22%), friend(s) (f:24, 19%), sibling(s) (f:19, 15%), father (f:15, 12%) and others (mother, uncle, cousin) (f:18, 14%). The fourth question was *"Who is your idol in wrestling?"* 96 out of 129 participants (74%) reported that there is an inspiring wrestler figure who is inspiring them. Of all the wrestling figures two Turkish wrestling champions are prominent. The first one is Taha AKGÜL (f = 27, 21%). He is nine times European Champion, twice World Champion, and holder of once Olympic Champion title. The second inspiring wrestler is Rıza KAYAALP (f = 26, 20%). He is twelve times European Champion, four times World Champion, and

holder of one silver and two bronze Olympic medals. The remaining 36 participants' responses to that question were analyzed and their idols were varied. Thus, they grouped under the "other" category. Because of the age group of the participants, the idols were mainly composed of the recent champions. The last question was *"Which family member support you in doing wrestling? Father, mother, or both?"* 104 out of 129 participants (90%) reported they receive father support, who encouraged them to take up wrestling. Further analysis of the motivators illustrated that the motivators are respectively Physical Education and Sports Teacher (f:28, 22%), friend(s) (f:24, 19%), sibling(s) (f:19, 15%), father (f:15, 12%) and others (mother, uncle, cousin) (f:18, 14%).

As a result, these findings supported H2 and H3, illustrating that supportive figures in the family or social network, as well as presence of idols wrestlers are associated with candidate wrestlers' motivation to take up wrestling, particularly in deprived regions.

Discussion

The present study aimed to investigate the social, educational, and personal factors that drive young candidate wrestlers from disadvantaged backgrounds and deprived regions to pursue wrestling as a sport. Through a cross-sectional survey design, the study focused on the demographics, socio-economic status, and the motivational antecedents of these young wrestlers. The participants, comprising 129 individuals aged 9 to 16, were carefully selected from relatively disadvantaged regions of Turkey, which historically have not been prolific in producing wrestlers. This research was conducted as part of a project initiated by the TWF, focusing on motivating and supporting youngsters from Eastern regions that are less prominent in wrestling. The findings of the study underscore the pivotal role of social influences in motivating young individuals to take up wrestling. Notably, the people around them played a significant role in their decision to pursue wrestling. The study indicated that key motivating figures include Physical Education Teachers (PETs) friends, siblings, and fathers. These individuals served as role models and sources of inspiration, illustrating the importance of mentorship and support from immediate social circles. Moreover, the presence of an idol wrestler in the lives of the young candidates was prevalent, with the majority expressing that having an idol encouraged them to engage in wrestling. These findings align with the socio-ecological framework of human development, emphasizing the significance of multiple layers of influence in shaping individuals' choices (Bronfenbrenner, 1979). Role models and mentors, such as PE teachers and familial figures, provide crucial support and guidance, influencing not only the decision to enter the sport but also the maintenance of a wrestling career. A noteworthy discovery was the substantial prevalence of idol wrestlers among the young participants, with around 70% reporting that an idol had encouraged them to embark on their wrestling journey. This finding aligns with Bandura's Social Cognitive Theory (Bandura, 1986), which posits that observing the achievements and behaviors of role models can instill a sense of self-efficacy and motivation. Idol wrestlers serve as sources of inspiration, offering tangible examples of success within the sport, and play a significant role in shaping the aspirations of these young athletes. This observation underscores the influence of established athletes in shaping the aspirations and choices of young aspirants. The educational and motivational camping periods organized by the TWF emerged as essential elements for engaging young wrestlers in the sport and motivating them to sustain their wrestling careers. Such initiatives provided a platform for fostering interest and commitment among participants. These findings align with previous research that highlights the significance of structured programs and events in fostering motivation and commitment to sports among young individuals (Eccles & Wigfield, 2002). These efforts are visible in the last European championship because there is a champion from these disadvantaged regions

of Türkiye. This could be an indicator of the importance of national sport policies addressing raising athletes from relatively disadvantaged regions in sports. The study further uncovers the impact of educational, motivational, and enjoyable camping periods on fostering sport engagement and sustaining wrestling careers. Such initiatives are in line with self-determination theory (Deci & Ryan, 1985), which underscores the importance of autonomy, competence, and relatedness in motivating individuals to engage in activities. The socio-economic background of the candidate wrestlers was also explored in this study. Nearly all the families represented in the study hailed from low-income groups. This highlights the potential of wrestling to serve as a means of empowerment for individuals from disadvantaged backgrounds, offering an avenue for personal development and success regardless of financial limitations. Similar studies have indicated that sports can serve as a vehicle for social mobility and self-improvement, enabling individuals to transcend their circumstances and achieve personal growth (Holt, 2008). The supportive environment and structured activities of the camping period likely fulfilled these psychological needs, enhancing the participants' enthusiasm for wrestling. Regarding the socio-economic context, the study highlighted that nearly all families of the candidate wrestlers came from low-income groups. This finding echoes with the broader literature on sports and social mobility, illustrating how sports can offer avenues for personal growth and achievement, irrespective of financial constraints (Coalter, 2007). As a result of this study wrestling is a sport that can be practiced with minimal equipment and resources, making it accessible to young people from underprivileged communities. The study also revealed that wrestling can be practiced in a variety of settings, including schools, community centers, and parks. Therefore, wrestling can be a viable option for young people who may not have access to more expensive sports due to financial constraints. Wrestling is one of the most accessible sports, requiring minimal equipment and facilities compared to other sports. This makes it an ideal option for young people from low-income or underprivileged communities who may not have access to more expensive sports (Witkowski & Czuba, 2019). Wrestling teaches discipline, self-control, and goalsetting, which can benefit young people from disadvantaged backgrounds. High school wrestlers scored higher on measures of discipline, self-control, and goalsetting compared to their non-wrestling peers. The researchers suggested that these skills could be valuable for young people from disadvantaged backgrounds, who may face additional challenges in achieving their goals (Swisher et al., 2013). Wrestling requires intense physical and mental training, as well as a strong work ethic and focus. These skills can help young people develop the discipline and self-control necessary to overcome challenges in other areas of their lives. Wrestling provides opportunities for academic and career success. Wrestling can be a pathway to college scholarships and professional opportunities, which can be particularly valuable for young people from disadvantaged backgrounds. High school wrestlers had higher GPAs and were more likely to attend college compared to their non-wrestling peers. Additionally, wrestlers who continued to compete at the collegiate level had higher graduation rates and were more likely to pursue postgraduate education (Davis et al., 2016). Wrestlers who excel in the sport may also develop important life skills, such as teamwork, leadership, and perseverance, which can be useful in a range of careers. Wrestling offers a sense of community and belonging. Wrestling teams often foster a strong sense of camaraderie and support among teammates. For young people from underprivileged communities, who may not have access to other forms of community support, wrestling can provide a sense of belonging and connection. Wrestling can promote physical and mental health. Wrestling is a demanding sport that requires intense physical conditioning, which can improve overall health and well-being. Additionally, the mental discipline required for wrestling can help young people develop resilience and coping skills that can be useful in managing stress and anxiety. Wrestling was associated with improved physical fitness, self-esteem, and mental health among adolescent

boys. The researchers suggested that the intense physical and mental demands of wrestling could help young people develop important life skills and coping strategies. Results suggest that participating in physical activity can lead to positive self-esteem among adolescent girls, particularly for younger girls and those at greatest risk of overweight. These findings highlight the necessity of promoting physical activity among adolescent girls as a method of fostering positive self-worth (Schmalz et al., 2007). Participation in wrestling was associated with a greater sense of community and belonging among high school students. The researchers suggested that this sense of connection may be particularly important for young people from disadvantaged backgrounds, who may face social isolation or marginalization (Gilchrist et al., 2017). It is important to acknowledge certain limitations of this study. The cross-sectional survey design provides a snapshot of the participants' motivations and backgrounds at a specific point in time, limiting the ability to establish causality or capture changes over time. Additionally, while the sample size was appropriate for the study's scope, the findings may not be fully generalizable to other contexts or regions.

Conclusion

This study shed light on the motivations behind young wrestlers from disadvantaged backgrounds and regions in Turkey to engage in wrestling. The influence of individuals in their social circles, particularly PETs, friends, siblings, and idols, emerged as key factors driving their interest. Educational and motivational initiatives organized by the Turkish Wrestling Federation played a vital role in nurturing their engagement and commitment. The socio-economic context further emphasized the potential of sports to provide opportunities for personal development and growth, even in the face of financial constraints. These findings contribute to our understanding of the complex interplay between social, educational, and personal factors that shape the choices and motivations of young athletes. The study has provided valuable insights into the motivations of young candidate wrestlers from disadvantaged backgrounds and regions. The roles of influential individuals, including PETs, friends, siblings, fathers, and idol wrestlers, were pivotal in sparking and sustaining their interest in wrestling. Additionally, the organized camping period emerged as a potent tool for enhancing engagement, motivation, and continuation of their wrestling endeavors. The socio-economic context, characterized by low-income families, underscores the transformative potential of sports in empowering individuals to transcend their circumstances.

The findings of this study hold implications for both policy and practice within the realm of sports and youth development. Firstly, the emphasis on role models and mentorship suggests that programs aimed at fostering sports engagement should incorporate opportunities for interaction with accomplished athletes, allowing young individuals to connect with real-life success stories. Moreover, the positive impact of structured camping initiatives highlights the importance of creating supportive environments that cater to participants' psychological needs for autonomy, competence, and relatedness. For policymakers and organizations like the Wrestling Federation, these findings underscore the significance of targeting less prominent regions and offering tailored programs that encourage youth participation in sports. Such initiatives have the potential to not only increase sport engagement but also contribute to personal development, self-confidence, and social cohesion among youth from disadvantaged backgrounds. Overall, we can conclude that sport is a tool with great educational potential for working with youth from socially vulnerable backgrounds, especially for the younger participants (Lopez & Kirk, 2022). However, students from low SES were less active than those from higher SES. Key barriers preventing low SES groups participating in sport and physical activity included time (mainly due to academic commitments), cost and a lack of confidence (Griffiths et al.,

2020). In line with this, why youth drop out of sports have three reasons and constraints. Intrapersonal constraints include lack of enjoyment (not having fun, being bored); low perceptions of physical competence; intrinsic pressures (e.g., stress); and perceptions of negative team dynamics (negative feelings toward team or coach). Interpersonal constraints include parental pressure and loss of feelings of ownership and not having enough time to participate in other age-appropriate activities. Finally, structural constraints include time (for training and travel), injuries, cost, and inadequate facilities (Witt & Dangi, 2018). Considering gender as a barrier on sport, male dominated discourses, practices and infrastructures still represent a significant disadvantage for women (Robles, 2019).

From this study results, despite wrestlers have some disadvantages in social status such as the lack of wrestling authority in family members, camping affected them positively and encouraged them wrestling career. Prospective wrestlers had declared that they come from low-income families underlines the socio-economic difficulties. It is thought that situations such as conducting the study in a seaside camp in a 5-star hotel, recognizing idol athletes increase the children's interest in wrestling sport and will have a positive effect on their future sports life despite their disadvantaged backgrounds.

References

Atkinson, J. (2002). *Trauma trails, recreating song lines: the transgenerational effects of trauma in Indigenous Australia*. North Melbourne: Spinifex Press.

Baić, M., Karninčić, H., Šprem, D. (2014). Beginning age, wrestling experience and wrestling peak performance–trends in period 2002–2012. *Kinesiology, 46*(1), 95–101. https://hrcak.srce.hr/127859

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Prentice-Hall, Inc.

Barnes, J. C., & Dickey, J. P. (2011). Wrestling: A sport for all. *Journal of Physical.*

Education, Recreation & Dance, 82(1), 9-12. https://doi.org/10.1080/07303084.2011.10598668

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.

Coalter, F. (2007). *A wider social role for sport: Who's keeping the score*? Routledge.

Connelly, L. M. (2016). Cross-Sectional Survey Research. Medsurg Nursing, *25*(5), 369–370. https://www.proquest.com/openview/8983376f0ff904653bbc4c0e27a89374/1?pq-origsite=gscholar&cbl=30764

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson.

Davis, J. R., Campbell, B. J., & Housh, T. J. (2016). The impact of high school wrestling on academic and career success. *Journal of Physical Education, Recreation & Dance, 87*(3), 47–51.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior.* Springer US.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53, 109–132.

Eurostat (2024). https://ec.europa.eu/eurostat/cache/RCI/#?vis=nuts2.labourmarket&lang=en

Gilchrist, E., Hauser, M., McLeod, L., & Rivenburgh, N. (2017). "You get that family vibe": A qualitative exploration of sense of community among high school wrestlers. *Journal of Youth and Adolescence, 46*(3), 484–496.

Griffiths, K., Moore, R., & Brunton, J. (2020). Sport and physical activity habits, behaviours and barriers to participation in university students: an exploration by socio-economic group, *Sport, Education and Society*, *27*(201), 1–15. https://doi.org/10.1080/13573322.2020.1837766

Holt, N. L. (2008). *Positive youth development through sport*. Routledge.

López, L. M. G., & Kirk, D. (2022). Empowering children from socially vulnerable backgrounds through the use of roles in sport education, Sport, Education and Society, *27*(6), 676–688, https://doi.org/10.1080/13573322.2021.1897563

Mathisen, T. F., Kumar, R. S., Svantorp-Tveiten, K., & Sundgot-Borgen, J. (2022). Empowered, Yet Vulnerable: Motives for Sport Participation, Health Correlates, and Experience of Sexual Harassment in Female Combat-Sport Athletes. *Sports (Basel, Switzerland)*, *10*(5), 68. https://doi.org/10.3390/sports10050068

Ratel, S., Duché, P., & Williams, C. A. (2006). Muscle Fatigue during High-Intensity Exercise in Children. *Sports Medicine, 36*(12), 1031–1065. https://doi.org/10.2165/00007256-200636120-00004

Robles, P.R. (2019). Women's Wrestling: A 'fight' for the transformation of cultural schemas in relation to gender. *Societies*, 9, 8. https://doi.org/10.3390/soc9010008

Schmalz, D. L., Deane, G. D., Birch, L. L., & Davison, K. K. (2007). A longitudinal assessment of the links between physical activity and self-esteem in early adolescent non-Hispanic females. *The Journal of adolescent health: official publication of the Society for Adolescent Medicine*, *41*(6), 559–565. https://doi.org/10.1016/j.jadohealth.2007.07.001

Seward, J. J. (1987). The commodification of sport. *International Review for the Sociology of Sport,* 22 (3), 171–192. https://doi.org/10.1177/101269028702200303

Swisher, L., Schweitzer, R. D., & Stevenson, B. (2013). The relationship between high school wrestling and self-control, goal orientation, and academic achievement. *Journal of Wrestling Research, 2*(1), 1–9.

Torrebadella-Flix, X., & Gutiérrez-García, C. (2022). Boxing, jiu-jitsu, Greco-Roman wrestling and stick fencing in Barcelona. Sportsmen and social classes at the beginning of the 20th century. Revista de Artes Marciales Asiáticas. 17. 73–107. https://doi.org/10.18002/rama.v17i1.7257

Witkowski, K., & Czuba, M. (2019). Accessibility of wrestling as a sports discipline. *International Journal of Wrestling Science, 9*(1), 20–28.

Witt, P. A., & Dangi, T.B. (2018). Why children/youth drop out of sports. *Journal of Park and Recreation Administration,* 36, 191–199. https://doi.org/10.18666/JPRA-2018-V36-I3-8618

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LEUKOCYTE POPULATIONS DETECTION IN YOUNG ATHLETES IN RESTING PHASE BASED ON SCATTER PROPERTIES USING A FLOW CYTOMETRIC APPROACH

Ornela Marko[A, B, D]

Department of Movement and Health, Faculty of Physical Activity and Recreation Sports University of Tirana, Rruga Muhamet Gjollesha, 1023, Tirana, Albania
ORCID: 0009-0009-3467-812

Klotilda Vrenjo[A, C]

Department of Education and Health, Faculty of Movement Sciences, Sports University of Tirana, Rruga Muhamet Gjollesha, 1023, Tirana, Albania
ORCID: 0000-0003-2917-4355

Majlind Sulçe[A, C, D]

Department of Morphofunctional Modules, Faculty of Veterinary Medicine, Agricultural University of Tirana, Rruga Paisi Vodica, Kodër Kamëz, 1029, Tirana, Albania
ORCID: 0000-0001-8827-2876 | e-mail: msulce@ubt.edu.al

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

Abstract Complete blood count analysis has a major importance as a first laboratory evaluation. In particular data obtained from complete blood count are relevant to correctly diagnose and follow up different medical conditions. In athletes, medical examinations and laboratory test are mandatory, especially when a sportive event will soon take place. Different automatic techniques are used to evaluate percentages of different leukocyte populations with a high accuracy. Flow cytometry represents a technology that is mainly used to diagnose different lymphoproliferative and myeloproliferative neoplastic disorders. In this study 127 samples from clinically healthy young athletes were collected and analyzed with both flow cytometry and automatic method to evaluate the usefulness of flow cytometry in detecting different leukocyte populations based on their scatter properties. Results showed that flow cytometry is a reliable technique having showed a high accuracy for different cell populations. Intra class correlation coefficient was >0.80 for all populations showing a high correlation between the two methods. However, a higher number of cases, the involvement of other automatic techniques are mandatory to confirm these results.

Key words: flow cytometry, leukocytes, populations, athletes

Introduction

Complete blood count (CBC) is usually the first step toward a correct diagnosis to different medical conditions. All data gained by this examination can help clinical practitioners to better understand the origin of the clinical problems. In human medicine this exam is usually performed to detect different medical conditions and also for follow up purposes in cases of neoplastic disorders, especially when the leukocyte formula is affected (Seo & Lee, 2022; Ahmed et al., 2020; Juchnowicz et al., 2023; Agnello et al., 2021; Lassale et al., 2018). In athletes the CBC is an important exam that should take place periodically to observe changes that could have happened prior and after athletic events (Mairbäurl, 2013; Bachero-Mena et al., 2017; Wedin & Henriksson, 2020). Many parameters of complete blood count can change during exercise. Indeed, it was observed that red blood cells, hemoglobin concentration and the hematocrit values increase progressively during exercise, reaching the highest value during maximum exertion and then a linear decrease is observed (Ciekot-Sołtysiak et al., 2024) Each peripheral blood cell leukocyte populations can be examined by the classical method using microscopy. This technique has been used for many years, but nowadays the CBC is performed also by automatic techniques that have showed a high accuracy. However, automatic techniques have to be validated prior to their use in daily practice. To do such, other, already automatic validated techniques have to be used to compare results.

Flow cytometry represents a relatively new technique that can be used to identify different leukocyte populations using its scatter properties and antibodies. This type of machinery has been used for many years now in human and veterinary medicine. Mainly, flow cytometry is used to diagnose peripheral blood neoplastic disorders such as lymphoma and leukemia, allergies, Ki67 also known as Kiel 67 which is a nuclear protein strictly associated and used as a cell proliferation marker, cell apoptosis, minimal residual disease, DNA content and other conditions (Morse et al., 1994; Rütgen et al., 2021; Kim & Sederstrom, 2015; Mao et al., 2023; Wlodkowic et al., 2009; Wlodkowic et al., 2011; Boumiza et al., 2005; Otto et al., 2016). Research conducted lately in animals shows that flow cytometry can be used also to identify and stage solid tumors such as mast cell tumors in dogs (Sulce et al., 2018). However, the reliability of this technique in solid tumors has to be further investigated. The main advantage of flow cytometry is that cells populations can be analyzed for the presence of different antigens in their surface at the same time (Robinson et al., 2023; Drescher et al., 2021; Sanders & Mourant, 2023). On the other hand also, single cells can be analyzed and sorted anytime if needed (Telford, 2023; Mattanovich & Borth, 2006; Atajanov et al., 2018; Box et al., 2020; Hervieu et al., 2022). On the contrary other techniques such as western blot and histopathology cannot give such information, taking into consideration also the time needed to provide results.

Taking into consideration all of the above mentioned capacities we hypothesized that flow cytometry can be used to correctly detect different leukocyte populations in young athletes using only its scatter properties. The aim of this study was to evaluate the reliability of flow cytometry in identifying leukocyte cell populations in young athletes using cell morphological properties.

Material and methods

The experiment was conducted with the permission of the ethical committee for research of the University of Sports of Tirana/Albania (protocol number 167/1/2024).

Sampling

Young athletes aging between 19–23 years old in resting phase were chosen for this study. A total of 127 athletes were included in the study. One sample corresponds to one individual. Athletes were included in the study only if they met the following criteria: clinically healthy, vaccinated following the national program of vaccination, no chronic diseases, no clinical signs of any disease at the moment of the peripheral blood collection, presence of a medical statement that they are completely healthy. Peripheral blood collection was conducted at the cephalic vein by a professional, while maximum efforts were made to minimize distress following the best practices.

Flow Cytometry analyzes

Samples were collected and deposit in Ehtylentetracetat 2.5 ml tubes. Samples were stored in refrigerated conditions in 4°C. In all cases analysis were performed within 24h from collection in order obtain optimum results avoiding any cell deformation or damage. Concentration of cells was determined using an Attune NxT flow cytometer (Thermo Fisher Scientific). A determined quantity of 50 µl (concentration 1×10^{6}) was placed in flow cytometry tubes. A lysis step of 15 minutes took place immediately after placement in order to destroy the red blood cell integrity. Cells were than centrifuged at 1200 rpm × 5 min, supernatant was discarded and a washing step using phosphate saline buffer (PBS) was performed. Cells were then resuspended in 200 µl of PBS and acquisition in the cytometer took place. A total of at least 1×10^{6} cells were acquired in order to provide reliable results on cell populations. Propidium iodide was used in the second channel in order to exclude debris from the analysis. Individual gates were designed for each cell population. Thus, data regarding percentages for Granulocytes, Monocytes and Lymphocytes were collected for all samples.

Automated analyses

Peripheral blood samples collected were analyzed by an automatic technique using SYSMEX XN-550 fully automated machinery. All samples were analyzed within 24h from blood collections and all results were provided 2 hours after all samples were analyzed.

Statistical analyses

Data obtained from Flow Cytometry and the automatic technique were summarized and descriptive statistics were done. Intra class correlation (ICC) coefficient was performed in order to observe the agreement between flow cytometry and the automatic technique using the automatic technique as the reference method. Two way mixed model and the definition of absolute agreement was used to calculate the ICC for single measures. The ICC was interpreted as poor if its 95% confidence interval is less than 0.5, moderate if between 0.5 and 0.75, good if between 0.75 and 0.9 and excellent if above 0.90 (Koo & Li, 2016). Statistical analyses was performed using SPSS version 25 (IBM,SPSS Inc., Chicago IL).

Results

In total one hundred and twenty seven samples were collected from healthy athletes for this preliminary study. Automated and Flow Cytometry techniques were used to analyze all samples. Statistical analyses were made based on percentages of each population taken into consideration. Interclass correlation coefficient showed that

flow cytometry and automated technique have a great agreement especially for Granulocytes and Lymphocytes. The level of agreement for Monocytes can be considered as moderate to good. Descriptive statistic P value and interclass correlation coefficient are presented in table 1.

Table 1. Descriptive statistics for Granulocytes, Monocytes and Lymphocytes evaluated by automated technique and flow cytometry. Interclass correlation coefficient is showed along with other data

Leukocytes	Technique	Mean (%)	Minimum (%)	Maximum (%)	ICC	P value
Granulocytes	Automated	58.326	35.2	74.4		
	Flow Cytometry	58.422	34.7	72.7	0.981	<0.001
Monocytes	Automated	7.434	5.2	16.0		
	Flow Cytometry	7.110	5.1	15.3	0.834	<0.001
Lymphocytes	Automated	31.148	17	47.1		
	Flow Cytometry	31.142	16.8	49.2	0.982	<0.001

In table 2 and 3 data regarding age, gender, place of living (rural or urban) and type of sport (individual or team) are presented

Table 2. Data regarding the age of the athletes involved in the study

Parameter	Average	Minimum	Maximum	SD
Age	19.67	19	23	0.895

Table 3. Data regarding place of living, gender and type of sport of athletes involved in the study

Place of living	Percentage	Gender	Percentage	Type of sport	Percentage
Urban	72.44	Male	70.86	Individual	62.99
Rural	27.56	Female	29.14	Team	37.01

In figure 1 data designation and gating strategy of different gates on flow cytometry in order to calculate each cell populations is presented.

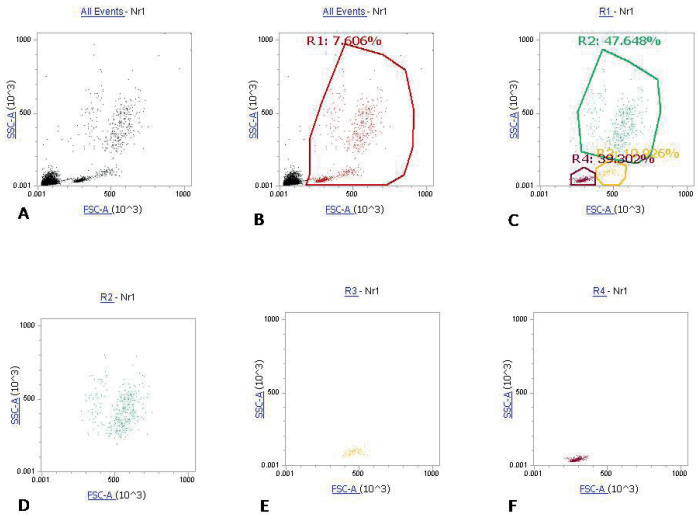

Figure 1. Gating strategy followed to evaluate each leukocyte population. (A) Dot plot representing all populations including debris, (B) All population leukocyte gating excluding debris, (C) Designation of gates for each leukocyte populations, (D) Activation of Granulocytes gate, (E) Activation and evaluation of Monocytes gate, (F) Activation of Lymphocytes gate

Discussion

Flow cytometry appears a reliable technique when the leukocyte populations identification is considered. Flow cytometry showed a high interclass correlation coefficient with the classical automated technique confirming almost the same results. Scatter properties of the machine were able to correctly identify the different leukocyte populations with a high accuracy. A high interclass correlation coefficient was observed for Granulocytes and Lymphocytes. Regarding Monocytes flow cytometry tend to underestimate their number when compared with the automated technique. This discordance can be due to the scatter properties presented by Monocytes in different stages of their activation. Moreover, in some cases it was difficult to design the proper gate for Monocytes since sometimes large Lymphocytes can enter to the gate by altering the percentages. As showed in figure 1 gates of Monocytes and Lymphocytes are located very near to each other causing time to time changes in their respective percentages. However, in the majority of cases gate designation was done properly and populations were well separated from each other. Moreover, in total results obtained from this study can be considered as satisfactory even if there are some limitations. The low number of caseload and missing the usage of other techniques such as microscopy and cell sorter can be considered as a big limitation for this study.

Limitations of the study

It has to be mentioned that the study has several limitations. Taking into consideration that this study is focused on the comparison of two different techniques the number of cases can be considered as relatively low. Moreover, the lack of antibody usage can slightly affect the results obtained during this investigation. Furthermore,

the use of a cell sorter can provide a larger information on the purity of the cell populations on each gate of analyses taken into consideration to obtain the different percentages.

Conclusions

Flow cytometry showed a high reliability for Lymphocytes and Granulocytes and moderate for Monocytes. These results showed that both techniques have a great agreement between each other demonstrating that flow cytometry can be routinely used to perform regular complete blood count in different situations.

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References

Agnello, L., Giglio, R. V., Bivona, G., Scazzone, C., Gambino, C. M., Iacona, A., Ciaccio, A. M., Lo Sasso, B., & Ciaccio, M. (2021). The Value of a Complete Blood Count (CBC) for sepsis diagnosis and prognosis. *Diagnostics, 11*, 1881. https://doi.org/10.3390/diagnostics11101881

Ahmed, M. M., Ghauri, S. K., Javaeed, A., Rafique, N., Hussain, W., & Khan, N. (2020). Trends of utilization of Complete Blood Count parameters for patient management among doctors in Azad Kashmir. *Pakistan Journal of Medical Sciences, 36*(5), 999–1004. https://doi.org/10.12669/pjms.36.5.1885

Atajanov, A., Zhbanov, A. & Yang, S. (2018). Sorting and manipulation of biological cells and the prospects for using optical forces. *Micro and Nano Systems Letters, 6*(2). https://doi.org/10.1186/s40486-018-0064-3

Bachero-Mena, B., Pareja-Blanco, F., González-Badillo, J. J. (2017). Enhanced strength and sprint levels, and changes in blood parameters during a complete athletics season in 800 m high-level athletes. Frontiers in Physiology, *8,* 637. https://doi.org/10.3389/fphys.2017.00637

Boumiza, R., Debard, A. L., & Monneret, G. (2005). The basophil activation test by flow cytometry: Recent developments in clinical studies, standardization and emerging perspectives. *Clinical and Molecular Allergy, 3*(9). https://doi.org/10.1186/1476-7961-3-9

Box, A., DeLay, M., Tighe, S., Chittur, S. V., Bergeron, A., Cochran, M., Lopez, P., Meyer, E. M., Saluk, A., Thornton, S., & Brundage, K. (2020). Evaluating the effects of cell sorting on gene expression. *Journal of Biomolecular Techniques, 31*(3), 100–111. https://doi.org/10.7171/jbt.20-3103-004

Ciekot-Sołtysiak, M., Kusy, K., Podgórski, T., Pospieszna, B., Zieliński, J. (2024) Changes in red blood cell parameters during incremental exercise in highly trained athletes of different sport specializations. *Peer-Reviewed Journal*, (27)12: e17040.

Drescher, H., Weiskirchen, S., & Weiskirchen, R. (2021). Flow cytometry: A blessing and a curse. *Biomedicines, 9*(11), 1613. https://doi.org/10.3390/biomedicines9111613

Hervieu, C., Verdier, M., Barthout, E., Bégaud, G., Christou, N., Sage, M., Pannequin, J., Battu, S., & Mathonnet, M. (2022). A label-free cell sorting approach to highlight the impact of intratumoral cellular heterogeneity and cancer stem cells on response to therapies. *Cells, 11*(15), 2264. https://doi.org/10.3390/cells11152264

Juchnowicz, D., Dzikowski, M., Rog, J., Waszkiewicz, N., Karakuła, K. H., Zalewska, A., Maciejczyk, M., & Karakula-Juchnowicz, H. (2023). The usefulness of a complete blood countin the prediction of the first episode of schizophrenia diagnosis and its relationship with oxidative stress. *PLoS ONE, 18*(10), e0292756. https://doi.org/10.1371/journal.pone.0292756

Kim, K. H., & Sederstrom, J. M. (2015). Assaying cell cycle status using flow cytometry. *Current Protocols in Molecular Biology, 111*, 28.6.1–28.6.11. https://doi.org/10.1002/0471142727.mb2806s111

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–63. https://doi.org/10.1016/j.jcm.2016.02.012

Lassale, C., Curtis, A., Abete, I., Van Der Schouw, Y. T., Verschuren, W. M. M., Lu, Y., & Bueno-de-Mesquita, H. B. A. (2018). Elements of the complete blood count associated with cardiovascular disease incidence: Findings from the EPIC-NL cohort study. *Scientific Reports, 8*, 3290. https://doi.org/10.1038/s41598-018-21661-x

Mairbäurl, H. (2013). Red blood cells in sports: Effects of exercise and training on oxygen supply by red blood cells. *Frontiers in Physiology, 4*, 332. https://doi.org/10.3389/fphys.2013.00332

Mao, X., Li, Y., Liu, S., He, C., Yi, S., Kuang, D., Xiao, M., Zhu, L., & Wang, C. (2023). Multicolor flow cytometric assessment of Ki67 expression and its diagnostic value in mature B-cell neoplasms. *Frontiers in Oncology, 13*, 1108837. https://doi.org/10.3389/fonc.2023.1108837

Mattanovich, D., & Borth, N. (2006). Applications of cell sorting in biotechnology. *Microbial Cell Factories, 5*(12). https://doi.org/10.1186/1475-2859-5-12

Morse, E. E., Yamase, H. T., Greenberg, B.R., Sporn, J., Harshaw, S. A., Kiraly, T. R., Ziemba, R. A., & Fallon, M. A. (1994). The role of flow cytometry in the diagnosis of lymphoma: a critical analysis. *Annals of Clinical and Laboratory Science, 24*(1), 6–11.

Otto, G., Lamote, A., Deckers, E., Dumont, V., Delahaut, P., Scippo, M. L., Pleck, J., Hillairet, C., & Gillard, N. (2016). A flow-cytometry-based method for detecting simultaneously five allergens in a complex food matrix. *Journal of Food Science and Technology, 53*(12), 4179–4186. https://doi.org/10.1007/s13197-016-2402-x

Robinson, J. P., Ostafe, R., Iyengar, S. N., Rajwa, B., & Fischer, R. (2023). Flow cytometry: The next revolution. *Cells, 12*(14), 1875. https://doi.org/10.3390/cells12141875

Rütgen, B. C., Baumgartner, D., Fuchs-Baumgartinger, A., Rigillo, A., Škor, O., Hammer, S. E., Saalmüller, A., & Schwendenwein, I. (2021). Flow cytometric assessment of ki-67 expression in lymphocytes from physiologic lymph nodes, lymphoma cell populations and remnant normal cell populations from lymphomatous lymph nodes. *Frontiers in Veterinary Science*, *8*, 663656. https://doi.org/10.3389/fvets.2021.663656

Sanders, C. K., & Mourant, J. R. (2013). Advantages of full spectrum flow cytometry. *Journal of Biomedical Optics, 18*(3), 037004. https://doi.org/10.1117/1.JBO.18.3.037004

Seo, I. H., & Lee, Y. J. (2022). Usefulness of Complete Blood Count (CBC) to assess cardiovascular and metabolic diseases in clinical settings: A comprehensive literature review. *Biomedicines, 10*(11), 2697. https://doi.org/10.3390/biomedicines10112697

Sulce, M., Marconato, L., Martano, M., Iussich, S., Dentini, A., Melega, M., Miniscalco, M., & Riondato, F. (2018). Utility of flow cytometry in canine primary cutaneous and matched nodal mast cell tumor. *The Veterinary Journal, 242,* 15–23. https://doi.org/10.1016/j.tvjl.2018.10.004

Telford, W. G. (2023). Flow cytometry and cell sorting. *Frontiers in Medicine 10*, 1287884. https://doi.org/10.3389/fmed.2023.1287884

Wedin, J. O., & Henriksson, A. E. (2020). The influence of floorball on hematological parameters: Consequences in health assessment and antidoping testing. *Journal of Sports Medicine, 2020*, 6109308. https://doi.org/10.1155/2020/6109308

Wlodkowic, D., Skommer, J., & Darzynkiewicz, Z. (2009). Flow cytometry-based apoptosis detection. *Methods in Molecular Biology, 559,* 19–32. https://doi.org/10.1007/978-1-60327-017-5_2

Wlodkowic, D., Telford, W., Skommer, J., & Darzynkiewicz, Z. (2011). Apoptosis and beyond: Cytometry in studies of programmed cell death. *Methods in Cell Biologyl, 103*, 55-98. https://doi.org/10.1016/B978-0-12-385493-3.00004

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DEVELOPING BASIC FOOTBALL TECHNIQUES MODEL IN FOOTBALL SCHOOLS

Arsil[A, D]

Faculty of Sport Science, Padang State University, Jl, Prof. Hamka Air Tawar, Padang City 25131, Indonesia
ORCID: 0009-0002-0250-6622 | e-mail: arsilfik@gmail.com

Anton Komaini[A, D]

Faculty of Sport Science, Padang State University, Jl, Prof. Hamka Air Tawar, Padang City 25131, Indonesia
ORCID: 0000-0002-2955-0175

Sri Gusti Handayani[B]

Faculty of Sport Science, Padang State University, Jl, Prof. Hamka Air Tawar, Padang City 25131, Indonesia
ORCID: 0000-0002-6939-8876

Heru Andika[C]

Faculty of Sport Science, Padang State University, Jl, Prof. Hamka Air Tawar, Padang City 25131, Indonesia
ORCID: 0009-0008-6112-5356

Muhamad Ichsan Sabillah[D]

Faculty of Sports and Health Sciences, Yogyakarta State University, Jl. Colombo No 1, Karang Malang, Caturtunggal, Daerah Istimewa Yogyakarta, 55281, Indonesia.
ORCID: 0000-0001-6081-8590

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

Abstract In this study, a basic football training model for students at Padang football schools is developed. The method employed in this research was research and development on the basis of Borg and Gall's references; data from needs analysis were collected and then used to create a training model. The data were analyzed statistically to determine the effectiveness of this model. The mean difference test (*t*-test) is utilized to determine the difference between the structurally controlled exercise group and the uncontrolled group. The sample in this study involved 32 football school students aged 11–12 years. After the entire research process was conducted, a basic game-based training technique model was generated, which was named the Football Basic Technique Training Model. The results of data analysis and interpretation show that (1) the model follows the principles of necessary skills training in playing football; (2) it is useful to be used to optimize the basic technical skills of playing football; and (3) it can be applied as a guide in carrying out the training process, especially for children aged 11–12 years.

Key words: training, football player, coaching, exercise, training project

Introduction

Football can be a great force for unity. Emral says that through football, Indonesia has become known to the world. In 1956, Indonesian football, coached by Autun "Toni" Pogacknik, held the Soviet Union to a 0–0 draw during the Melbourne Olympics in Australia. Two years later, Indonesian football won a bronze medal at the 1958 Asian Games in Tokyo, Japan. The pinnacle of Indonesian football was when it won a gold medal for the first time at the 1987 Sea Games. Owing to these achievements, Indonesia has been tagged as the "Brazil" of Asia (Emral & Tangkudung, 2015).

To become unmatched in football, one must practice basic football techniques in their early childhood in football schools to optimize their basic technical skills in football. The lack of attention to early childhood (*grassroots*) and youth (age groups) is one of the leading causes of failure in national football management. How football in any country is developed is determined by how the players are molded at an early age. Moreover, FIFA and AFC, through the program *Vision* of Asia, highlight the importance of coaching, especially at the *grassroots* level, age of 6–13 years.

Training aspects that must be developed in young children are especially basic movement skills (techniques) with good basic physical abilities. A young football athlete would be trained and nurtured comprehensively to become a professional player through the academy (Williams & Reilly, 2000). Therefore, trainers must understand the aspect of training stages of exercise in terms of when and how much the portion of the training is used for *multilateral* and specialization. High-quality football playing techniques can be developed if young players (*grassroots* and *youth*) are properly trained and guided. Trainers must also consider the risk of injury in early childhood. Zarei et al. (2020) said that a warm-up program for children aged 11 years and older must be developed to prevent injuries.

Mastering and performing one kind of technique requires regular practice and takes a long time until it is finally executed automatically. Indonesian Football Association (PSSI) explains that when playing for 90 minutes of standard time, players must always move with or without the ball such as dribbling *the ball* to pass the opponent, *passing* to a co-player for ball possession (*ball possession*), and shooting at the opponent's goal to score a goal (PSSI, 2016). Basic technical skills in playing football dramatically affect the ability to play football. *Dribbling, passing,* and *shooting* the ball into the goal are elements of basic techniques in football.

Regular and programmed training carried out from an early age, coupled with other tactical and physical exercises, will improve the basic techniques of *dribbling, passing,* and *shooting* the ball into the goal. Varied exercises will establish a training atmosphere that encourages interest in practicing diligently. Trainers must develop training model programs in exercises of *fundamental*, *game-related, and game situations*.

Fostering and developing football's sport toward maximum achievement cannot be separated from the elements that will support the achievement. Football entails many factors that influence achievement. As expressed by Syafruddin (2011), two factors influence achievement, namely, internal and external ability factors. As stated by Kostikova (2015), sports motivation training and a sense of trust optimize sports activities' effectiveness during critical games.

Given that the situation is caused by several factors, which include the trainer's limited ability and the limited resources used to support the training process, based on researchers' observations in the field, the training process at the Padang City Football School, to date, is not effective in providing proper training to children at an early age. This is confirmed by the fact that most of the coaches in Padang City football schools are not outstanding and typically have limited competence and experience in football.

Coaches tend to use traditional ways of training and rely on self-experience; thus, the kind of training provided is not suitable for children but for adults. Most of the coaches in football schools use conventional methods such as warming up, excessive time allocated to running, stretching, and game simulation, with no ball touch at all being used. Consequently, children can become less motivated by football. Isidori et al. (2015) explained that the lack of awareness of the paradigms that guide sports activities is severe, primarily when one trains young athletes, and in sports such as football, in which opportunities to develop critical thinking and reflective attitudes are few and flawed due to cultural traditions, often understanding this sport only in the context of competence and high performance, trainers must be able to tailor the training skills to the child's age level.

In contrast, student experiences of learning control and agitation can have a more considerable influence on attitudes, cognitions, or emotions that are specifically encountered during PE classes, including student interest, self-motivation, and subjective vitality, in comparison to student life skills growth in PE that may occur more subtly or indirectly (Cronin et al., 2019). Should a trainer organize and modify exercises according to the needs and the appropriate age group to motivate the trained children with enthusiasm in catching what is being directed? FIFA states that a professional coach must implement or carry out nine points to achieve the desired goals and expectations from a training process (FIFA, 2016). Van de Pol et al. (2012) said in their research that a coach who can create a motivational climate would influence players in the context of training and competition. Moreover, players' stamina to some degree (exhaustion) can be improved as a result of addressing the continuing difficulties encountered by the football players (e.g., improved training) and by deeming their long-term ambitions (e.g., career development) to becoming more realistic (Adie et al., 2012).

High-quality football playing skills result from a good training process with continuous coaching done correctly, excellently, and purposefully (DeWeese et al., 2015; Langdon et al., 2017). Besides motor skills training, it determines the skills to play football (Komaini & Mardela, 2018; Komaini, 2017). Of course, it must be oriented toward coaching, which includes tactics (Teodorescu & Gheorghe, 2014), technique and physical abilities (Christopher et al., 2016; Dillon et al., 2018), and mental abilities (Slimani et al., 2014; Thøgersen-Ntoumani et al., 2005). To hone players who can become great players at their golden age, they must be supported by external factors such as having a quality coach (Teodorescu & Gheorghe, 2014; Pink et al., 2018) with the provision of a form of training (Veugelers et al., 2016) to football players who can implement according to the potential possessed in the player himself and can give players an idea of the task in playing football.

The most important of exercises development that must be given to young players are skills (basic techniques) including basic movements that correspond to the conditions and situations of the football game with the basic physical abilities possessed. From several descriptions that have been previously presented, with researchers being interested in carrying out research that focuses on the basic techniques of football players in the team in depth based on scientific studies with the title of developing basic football techniques in football schools, the purpose of this research is to produce basic football training materials to optimize basic football technical skills at the age of 11–12 years in football schools to make football training more effective, efficient, and interesting.

Material and Methods

This development research is aimed at producing basic football training materials with a playing approach for football schools to make the training more effective, efficient, and attractive. The target in the research and development (R&D) of the football training model was 36 active football students aged 11–12 years old. The students

were grouped into two groups, namely, the experimental and control groups. Each group comprised 16 students. In this study, approval has been obtained from all samples and meets the requirements of research ethics. In this research, the 11- and 12-year-old football training model was established to develop and validate training products. Figure 1 illustrates the training. R&D in this exercise used a qualitative approach and used Borg and Gall's R&D model, comprising 10 steps. The development stage of the materials was then carried out in 10 stages of the model developed by Borg and Gall (Figure 2). Several procedures can be used in R&D, according to Borg and Gall, namely, (1) research and information gathering, (2) planning, (3) development of an early form of products, (4) study starters, (5) revision of the initial products, (6) main field trials, (7) product revisions, (8) field testing, (9) revision of the final products, and (10) deployment.

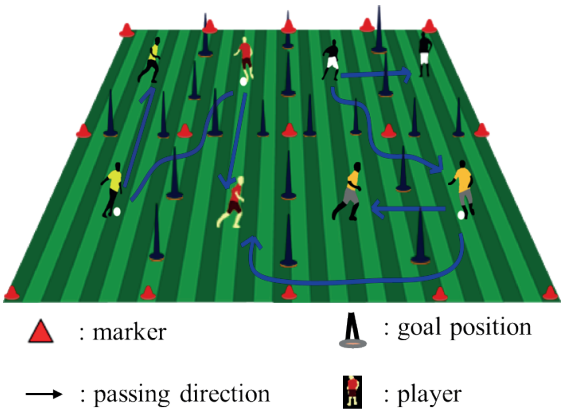

Figure 1. Illustration of the training model

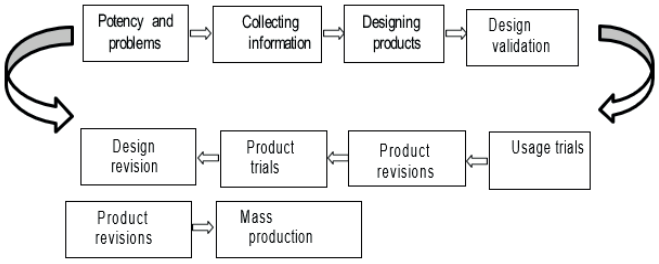

Figure 2. Steps for using the research and development method by Borg and Gall in Sugiyono (2014)

Two data from this study, namely, qualitative and quantitative data was collected and analysed. Qualitative data were obtained from (1) the results of interviews with Football School (FS) trainers, (2) field notes, and (3) data on suggestions for improvement of the draft of the initial model and the results of observations on the implementation

of small- and large-scale trials. Quantitative data were acquired from (1) assessment of the scale of the observation value of the training model implementation.

The questions in the interview involved (1) the experience of the football school (SSB) coach in training, (2) the length of time of the training carried out, (3) training facilities and infrastructure, (4) the length of time that the student/player in the age group of 11–12 years old is having training, (5) the form of the assessment carried out by the coach, (6) the training method given, (7) the most fundamental aspects of playing football, (8) the method of basic football techniques training, (9) problems that are often encountered during basic technical training, and (10) whether it is necessary not to develop a training model of basic football techniques for children aged 11–12 years.

Results and Discussion

Using the results of data acquired in the field from the beginning to the end of this study, researchers were able to summarize all the information needed in this study and obtain the following results.

Results of the development of the basic technique training model for playing football

The development of the training model for SSB students in Padang City was to produce a training model for basic technical skills for playing football, named the "Football Basic Technique Training Model." Preliminary study data acquired from the literature study results will be presented and analyzed through field observations conducted during training and competition activities in Padang City. Expert validation data were obtained via a questionnaire from three expert football coaches. Trial data from expert football coaches were collected using a questionnaire instrument for (1) the starting field test of 12 SSB students, (2) the main field trials of 30 SSB students consisting of three SSBs in Padang City, and (3) the field implementation test involving 60 SSB students consisting of six SSBs in Padang City. The SSB football students used in the trial were taken in simple random order. In this study, researchers wanted to determine the impact of using products including training projects carried out by Borg and Gall, so two groups must be formed, namely, the experimental group and the control group; hence, differences can be tested with *t*-tests. This technique can be employed to process the research data from the football coach expert as the subject of the trial (Table 1).

Table 1. Preliminary study data

No.	Component	Findings
1	**Preliminary studies** **a. Literature studies**	• The basic techniques in the game of football are: (1) passing the ball (passing), (2) dribbling, (3) shooting (shooting). • Doni Football Basic Technique Training Model is a form of training consisting of forms of playing exercises. • Learning motion produces change. • Appearance to a better level. For better skills to be possessed, it must first be developed. • Elements of motion are necessary, through the process of learning and practicing. • The skills of basic football techniques are easy to learn and analyze when displayed in visual form.

No.	Component	Findings
1	b. Needs analysis (through observation) in May 2017	• The exercises given have not been well programmed, in other words, the coach gives exercises based on what is remembered in the field. • Coaches have not used specific training models to improve basic football technique skills. • Field observation results after warm-ups are more directly playing 8 vs. 8 so the basic technical skills of children aged 11–12 years are relatively low because the number of touches they get is very small. • The exercises given have not focused on any of the required engineering elements. • The coach does not make direct corrections in case of error by stopping and demonstrating, but corrections are only through words while the game is still going on. In other words, training takes place, but coaching does not exist. • Field observations that the basic football skill training model carried out does not follow the principles of fundamental training, game-related, and game situation.
2.	**Expert Validation** a. The results of the expert validation of football coaches (n = 3) in August 2017 with a total of 234 instruments.	• From the validation of three expert football coaches obtained results (82.59%), detailed in the appendix on page 200, the Doni Football Basic Technique Training Model is very feasible to use. • Input from the three expert football coaches obtained that the training formation in the Doni Football Basic Technique Training Model needs to pay attention to the number of groups. • The three expert football coaches were given input to add fun games so that the training could be enjoyable to take.
3.	**Trial** Small-scale test results (n = 12) conducted August 27, 2017	• From small group trial results (82.56%), detailed in the appendix on page 207, which makes the Doni Football Basic Technique Training Model very feasible to use. • Some of the observations in this small group trial obtained field notes such as the following: (1) the width of the field area of the training form is too small, making it difficult for children to play, to further widen the distance of the training area. (2) When training, the distance between the posts forward and to the side needs to be considered again, so as not to disturb his other friend when doing games in other posts. (3) The formation when shooting the distance between players also needs to be considered, because it is too close so that it interferes with the concentration of the other group when shooting.
	Main field trial results (n = 30) September 3, 2017	• Based on field trials 30 players and 3 coaches obtained results (83.16%), detailed in the appendix on page 218; thus, the Doni Football Basic Technique Training Model is very feasible to use. • Based on the results of observations at this field trial, several field notes were obtained, including them being a little hesitant initially when doing training in the first session in the form of playing, but after discovering the mystery of the exercise, they enjoyed it, and they were very enthusiastic about doing it.
	Field test results (n = 60) September 17, 2017	• Based on field trials 60 players and six coaches obtained results (82.02%), detailed in the appendix on page 225, thus, the Doni Football Basic Technique Training Model is very feasible to use. • Field notes based on the results of observations at field trials obtained field records, including that players are very enthusiastic about doing it because this method is new to them and not boring. • In general, all students can carry out the instructions given based on the desired expectations.
	Model Final	• After a series of trials, revisions, and refinements on the draft model, a basic technique model of play-based football playing skills for students of SSB Padang City was compiled, which was named the "Doni Football Basic Technique Training Model," consisting of 15 forms of variations of passing practice models, 15 forms of variations of dribbling training models, and nine forms of shooting exercises. Thus, the total number of model variations presented in this paper is 39.

Expert validation

The average percentage of expert validation results for football training was 82.59%. The football training experts' suggestions are as follows: (1) input from three football coaches, that is, the training formation in the basic technical skills model for playing football should pay attention to the number of groups; (2) input from three expert football coaches, that is, to add *fun games* to make the training enjoyable.

Table 2. Football training expert validation result data n = 3 with 234 instruments and more complete questions

No.	Expert	Minimum score	Maximum score	Score result	Percentage
1.	Football Training Expert 1 Dr. Emral, M.Pd	234	1.170	970	82.90
2.	Football Training Expert 2 Dr. Alex Aldha Yudi, M. Pd	234	1.170	989	84.52
3.	Football Training Expert 3 Dr. Arsil, M.Pd	234	1.170	940	80.34
Average					82.59

Based on the description in Table 2, the average percentage of football training expert validation results is 82.59%.

Feasibility of training model for basic technique skills for playing football

The average percentage of data analysis results from three football coaches was 82.59%. Therefore, the training model for the basic technical skills of playing football is very feasible to use. Data analysis is based on the validation results of expert football coaches; each of these indicators is described in Table 3.

Table 3. Data analysis results from expert football coaches (n = 3)

No.	Dimension	Indicators	Score at least	Score maximum	Score result	Percentage
1	Training Materials Training Model Basic Skills Playing Football:	a) Objectives of the training material model Practice basic technique skills playing football 11	117	585	493	84.27
		b) Quality of training materials Practice model basic technical skills playing football	117	585	497	84.95
		c) Variations of practice materials Practice model basic technical skills playing football	117	585	479	81.88

No.	Dimension	Indicators	Score at least	Score maximum	Score result	Percentage
2	Practice Methods Practice Model Practice basic technical skills playing football	a) Systematics of practice methods Practice model basic technical skills playing football	117	585	466	79.65
		b) Effectiveness of the exercise methods Practice model basic technical skills playing football	117	585	492	84.10
		c) The appeal of the exercise model Practice basic technique skills of playing football	117	585	472	80.68
Sum			702	3510	2899	82.59

Effectiveness of the basic technique skills training model for playing football

After carrying out the initial field trials with n = 12, the second stage revision was conducted for the product components of the development of the basic technical training model for playing football, which was then continued with the main field trials with n = 30 onward and field trials with n = 60 revised stage 3. To determine the effectiveness of the product development model for the basic technique of playing football, the implementation process was carried out using the research design of *True Experimental Design* (*Pretest–Posttest Only Control Design*). The main characteristic of *True Experimental* is that the samples employed for experiments and as a control group are taken randomly from particular populations. To test the effectiveness of the application of the basic technique training model for playing football in SSB students, the "*t*-test" technique was utilized.

Test data analysis requirements

As a requirement for data analysis, a normality test was previously conducted on the data from the pretest and posttest basic technical skills of playing football using the Lilliefors test at a significant level of $p > 0.05$.

Table 4. Recapitulation of normality testing results of control and non-control group passing skills data

Group sample	Sum of the samples	L-count	L-table	Conclusion
Control group	16	0.203	0.213	Usual
Non-control group	16	0.199	0.213	Usual

Information:
Control Group: the group of students who are given the training treatment of developing basic techniques of playing football.
Non-control group: the group of students who were not given the training treatment of developing basic techniques of playing football.

Using the results of the calculation of the data normality test in Table 4, the calculated L-value for all basic pretest data of football passing was acquired; both the control and the non-control groups were smaller in terms

of L-value when compared with that in the L-table at a significant level of p > 0.05. Hence, it can be concluded that the entire pretest data of this basic football passing technique comes from a normally distributed population.

Table 5. Recapitulation of normality testing results of control and non-control group dribbling skills data

Group sample	Sum of the samples	L-count	L-table	Conclusion
Control group	16	0.094	0.213	Usual
Non-control group	16	0.143	0.213	Usual

Information:
Control group: the group of students who were given the exercise treatment of developing basic techniques of playing football.
Non-control group: the group of students who were not given the training treatment of developing basic football techniques.

Utilizing the results of the calculation of the data normality test in Table 5, the calculated value for all pretest data of the basic technique of football dribbling was achieved; both the control and the non-control groups were smaller than the L-table at a significant level of p > 0.05. Therefore, it can be concluded that all the pretest data of the basic technique of dribbling football come from a normally distributed population.

Table 6. Recapitulation of normality test results of control and non-control group shooting skills data

Group sample	Sum of the samples	L-count	L-table	Conclusion
Control group	16	0.192	0,213	Usual
Non-control group	16	0.153	0,213	Usual

Information:
Control group: the group of students who are given the training treatment of developing basic techniques of playing football.
Non-control group: the group of students who were not given the training treatment of developing basic techniques of playing football.

Using the results of the calculation of the data normality test in Table 6, the calculated value for all pretest data of the basic technique of football shooting, both the control and the non-control groups were smaller than the L-table at a significant level of p > 0.05 Hence, it can be concluded that the entire pretest data of this basic technique of football shooting comes from a normally distributed population. The "*t*-test" technique was employed to calculate the steps of testing the effectiveness of the application of the basic technique training model of playing football for SSB students.

t-test

After the data normality testing was completed, the next step was to test the football playing skill model using the *t*-test statistics. Table 7 presents the results of the calculations of the authors.

Table 7. *t*-test results

Group	Types of skills	N	unit	t-count	t-table
Control groups	Passing	16	Score	5.175	1.753
	Dribbling	16	Score	4.452	1.753
	Shooting	16	Score	3.464	1.753

Group	Types of skills	N	unit	t-count	t-table
Non-control group	Passing	16	Score	2.070	1.753
	Dribbling	16	Score	2.525	1.753
	Shooting	16	Score	1.962	1.753

Based on Table 7, the *t*-count value of the control group at the passing ability is 5.175 > *t*-table 1.753, whereas the *t*-count of the non-control group on the passing ability is 2.070 > *t*-table 1.753 because the calculation value is greater than that in the *t*-table; both the basic engineering exercise model that the author developed and the conventional exercise model have a significant influence. This means that the two models can enhance the basic playing skills of SSB Sepakbola West Sumatra students. When viewed from the calculation value, the control group has a better value (5.175) when compared to the non-control group (2.070); thus, it can be concluded that the basic football technique training model that the authors has, has a more significant influence when compared to conventional exercises, which means that the improvement of basic technique skills of playing the control group is better than that of the non-control group.

Supporting and inhibiting factors for the application of the basic technique training model for playing football for SSB students

Several activities strongly support applying the basic technique training model for playing football, which include the following: (1) the DANONE competition calendar every year, MENPORA U-12 Cup, in which their training target is to be selected as young Garuda national players, and (2) looking at many opportunities for the achievement, the coaching and development of basic techniques for playing football has flourished rapidly in football schools but has not yet been implemented as expected.

The application of the basic technical training model for playing football has not been appropriately implemented. Inhibiting factors include (1) the limited number of trainers with training licenses in various SSBs; (2) lack of supplies of training tools and equipment such as balls, vests, *cones*, markers, *portable goals*, and poorly maintained training fields; and (3) limited areas to practice for some SSBs.

Strengths and weaknesses of the basic technique training model for playing football for SSB students

The advantages of this basic technique of playing football training models are producing the final product in a manual and a video training model for basic technical skills in playing football. The book and video will be useful for SSB football coaches to guide the training process to improve performance effectiveness. Expectedly, these will increase the effectiveness of the training process for SSB students viewing the video training model for basic technical skills playing football, whether before or after the training process, and will make it easier for SSB coaches and students to understand the training material. Thus, viewing videos of intricate movements taking place quickly can be viewed slowly and repeated until they understand.

This basic technical training model's weakness for playing football is that it only displays a few basic techniques for playing football. In comparison, a player who can play football well must master all basic techniques: *dribbling*, *passing*, *controlling*, *heading*, and *shooting*. If a football player does not master the basic techniques of playing football, he/she cannot expect high achievements in defending the club and playing in the national team.

Conclusion

In conclusion, the training model developed is through the actual competition situation. This model is arranged according to the principles that exist in the phases of the football game. This model can be a reference for SSB football coaches in providing training. With the training material established in terms of ease of practice, variety, suitability, and the exercise's benefits, the model is simple and easy to understand. An exciting model is also packaged in the book and the video training model for the basic techniques of playing football to make it easier for coaches and students to understand the training material and increase the ongoing training process's effectiveness.

This floating product model can be used in SSB in Indonesia because all SSB students have the same principal characteristics. Before giving training, coaches and students can watch and study the manual and the animated videos so that SSB students can master the basic football training model exercises well. Thus, SSB coaches and students get additional information on how to train basic techniques, allowing the coaches and SSB students to use the basic technique training model for playing football as much as possible; it is necessary to have regular exercise and execution.

References

Adie, J. W., Duda, J. L., & Ntoumanis, N. (2012). Perceived coach-autonomy support, basic need satisfaction, and the well- and ill-being of elite youth soccer players: A longitudinal investigation. *Psychology of Sport and Exercise, 13,* 51–59. https://doi.org/10.1016/j.psychsport.2011.07.008

Christopher, J., Beato, M., & Hulton, A. T. (2016). Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Human Movement Science*, *48*, 1–6. https://doi.org/10.1016/j.humov.2016.03.013

Cronin, L., Marchant, D., Allen, J., Mulvenna, C., Cullen, D., Williams, G., & Ellison, P. (2019). Students' perceptions of autonomy-supportive versus controlling teaching and basic need satisfaction versus frustration in relation to life skills development in PE. *Psychology of Sport and Exercise*, *44*, 79–89. https://doi.org/10.1016/j.psychsport.2019.05.003

DeWeese, B. H., Hornsby, G., Stone, M., & Stone, M. H. (2015). The training process: Planning for strength – power training in track and field. Part 1: Theoretical aspects. *Journal of Sport and Health Science, 4,* 308–317. https://doi.org/10.1016/j.jshs.2015.07.003

Dillon, P. A., Kempton, T., Ryan, S., Hocking, J., & Coutts, A. J. (2018). Interchange rotation factors and player characteristics influence physical and technical performance in professional Australian Rules football. *Journal Science Medicine in Sport*, *21*, 317–321. https://doi.org/10.1016/j.jsams.2017.06.008

Emral, E., & Tangkudung, J. A. P. (2015). Development of dribbling basic technique skill of students of PSTS Tabing Padang football school. *JIPES, 1,* 12–20.

FIFA. (2016). *Grassroots*. Switzerland: RVA Druck Und Medien, Altstatten.

Isidori, E., Migliorati, M., Maulini, C. & Echazarreta R. (2015). Educational paradigms and philosophy of football coaching: a theoretical and practical perspective. *Procedia - Social and Behavioral Sciences*, *197*, 614–621. https://doi.org/10.1016/j.sbspro.2015.07.203

Komaini, A. (2017). Fundamental motor skills of kindergarten students (a survey study of the influence of financial condition, playing activity, and nutritional status). *IOP Conference Series Materials Science and Engineering*, *180*, 012156. https://doi.org/10.1088/1757-899X/180/1/012156

Komaini, A., & Mardela, R. (2018). Differences of fundamental motor skills stunting and non stunting preschool children in Kindergarten in North Padang. *IOP Conference Series Materials Science and Engineering, 335*, 012131. https://doi.org/10.1088/1757-899X/335/1/012131

Langdon, J. L., Schlote, R., Melton, B., & Tessier, D. (2017). Effectiveness of a need supportive teaching training program on the developmental change process of graduate teaching assistants' created motivational climate. *Psychology of Sport and Exercise*, *28*, 11–23. https://doi.org/10.1016/j.psychsport.2016.09.008

Kostikova, N. (2015). Psycho-pedagogical support in the preparation of young football players. *Procedia - Social and Behavioral Science*, *185*, 286–289. https://doi.org/10.1016/j.sbspro.2015.03.408

Pink, M. A., Lonie, B. E., & Saunders, J. (2018). The challenges of the semiprofessional footballer: A case study of the management of dual career development at a Victorian Football League (VFL) club. *Psychology of Sport and Exercise, 35*, 160–170. https://doi.org/10.1016/j.psychsport.2017.12.005

PSSI. (2016). *Manual lisensi "D" nasional.* Jakarta: PSSI.

Slimani, M., Hentati, A., Bouazizi, M., Boudhiba, D, Amar, I. B., & Cheour, F. (2014). Effects of self-talk and sophrological trainings on the development of self-confidence and managing emotions in Tunisian male kick boxers. *Journal of Humanities and Social Sciences*, *19*, 31–34. https://doi.org/10.9790/0837-19513134

Sugiyono. (2014). *Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D.* Bandung: Alfabeta.

Syafruddin. (2011). *Ilmu kepelatihan olahraga teori dan aplikasinya dalam pembinaan latihan.* Padang: UNP Press Padang.

Teodorescu, S., & Gheorghe, D. (2014). Methods for increasing the game action performance in football by valorizing the cognitive processes. *Procedia - Social and Behavioral Science*, *117*, 361–366. https://doi.org/10.1016/j.sbspro.2014.02.228

Thøgersen-Ntoumani, C., Fox, K. R., & Ntoumanis, N. (2005). Relationships between exercise and three components of mental well-being in corporate employees. *Psychology of Sport and Exercise, 6*, 609–627. https://doi.org/10.1016/j.psychsport.2004.12.004

van de Pol, P. K. C., Kavussanu, M., & Ring, C. (2012). Goal orientations perceived motivational climate, and motivational outcomes in football: A comparison between training and competition contexts. *Psychology of Sport and Exercise*, *13*, 491–499. https://doi.org/10.1016/j.psychsport.2011.12.002

Veugelers, K. R., Young, W. B., Fahrner, B., Harvey, J. T. (2016). Different methods of training load quantification and their relationship to injury and illness in elite Australian football. *Different methods of training load quantification and their relationship to injury and illness in elite Australian football, 19,* 24–28. https://doi.org/10.1016/j.jsams.2015.01.001

Williams, A. M., & Reilly, T. (2000). Talent identification and development in soccer. *Journal of Sports Science*, *18*, 657–667. https://doi.org/10.1080/02640414.2020.1766647

Zarei, M., Abbasi, H., Namazi, P., Asgari, M., Rommers, N., & Rossler, R. (2020). The 11+ Kids warm-up programme to prevent injuries in young Iranian male high-level football (soccer) players: A cluster-randomised controlled trial. *Journal Science and Medicine in Sport*, *23,* 469–474. https://doi.org/10.1016/j.jsams.2019.12.001

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FERRITIN LEVEL ANALYSIS TO IDENTIFY IRON DEFICIENCY IN QUALIFIED ATHLETES

Anna Husarova[A, B, C, D]

State Scientific Research Institute of Physical Culture and Sports, Ukraine
ORCID: 0000-0002-9950-3980 | e-mail: ivanova.anna.m@gmail.com

Nataliia Vdovenko[A, B, D]

State Scientific Research Institute of Physical Culture and Sports, Ukraine
ORCID: 0000-0002-3097-5920

Olena Maidaniuk[B, C, D]

State Scientific Research Institute of Physical Culture and Sports, Ukraine
ORCID: 0000-0003-0451-1847

Halyna Rossokha[B, D]

State Scientific Research Institute of Physical Culture and Sports, Ukraine
ORCID: 0000-0003-2173-5068

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

Abstract The world of elite sports is marked by intense physical and psychological strains, significantly augmenting the demands on athletes' bodies and rendering them susceptible to iron deficiency, and anemia, especially women athletes. Iron deficiency can have severe consequences, including heightened injury risks, delayed recovery following physical exertion, compromised immunity and diminished athletic performance. Notably, iron deficiency in athletes can persist without manifesting as anemia. Consequently, comprehensive research is crucial to identify iron deficiency states in athletes. Our study focused on researching the ferritin content and other indicators of iron metabolism in the blood of 159 qualified athletes (98 men and 61 women) who specialized in various sports. The research entailed the assessment of ferritin concentration, hemoglobin, iron content, red blood cell count, and hematocrit level. The findings revealed a considerable prevalence of hidden iron deficiency among female athletes, with 54% exhibiting prelatent iron deficiency and 16% presenting with latent iron deficiency. They require appropriate recommendations for treatment and prevention. The results of our research confirm the presence of the iron deficiency problem in athletes, especially women. Due to the above, identifying not only iron-deficiency anemia but also hidden iron deficiencies is crucial to ensure timely and effective treatment and prevention.

Key words: iron deficiency anemia, sport, female athletes, sex differences

Introduction

Approximately 1,2 billion people worldwide suffer from iron deficiency anemia and iron deficiency without anemia (Kassebaum et al., 2014). It is necessary to notice that the above concepts are considered synonymous, but this is a false opinion. Iron deficiency without anemia is a broader concept and indicates low iron reserves in the body, regardless of anemia (Al-Naseem et al., 2021). Symptoms of iron deficiency can be nonspecific and manifest themselves in the form of fatigue, difficulty concentrating, sleep problems, and a decrease in physical capabilities, which significantly impact a person's health and performance (DiSilvestro et al., 2020, Coates et al., 2017, Sim et al., 2019).

The problem of iron deficiency also applies to athletes. The main causes of iron deficiency in athletes include (Damian et al., 2021):

1. Iron loss due to excessive sweating, hematuria, gastrointestinal bleeding, nutritional changes (unbalanced nutrition, vegetarianism, consumption of foods that reduce iron absorption), and during menstruation.
2. Diseases of the gastrointestinal tract caused by loads (malabsorption syndrome).
3. Inflammation and intravascular/extravascular hemolysis that occur in response to significant physical exertion.

In assessing iron deficiency and in order to gain a better understanding of the physiological processes occurring in the body, scientists propose to be guided by the following classification of the stages of iron deficiency states (Damian et al., 2021, Alaunyte et al., 2015):

1. The prelatent stage of iron deficiency is characterized by decreasing tissue iron stores, increased iron resorption in the small intestine (according to radiological studies) and the presence of sideroblasts in the bone marrow. Hemoglobin and iron transport fund preserved. Peripheral blood counts and serum iron levels are within the normal range. There are no clinical manifestations.
2. The latent stage is characterized by the depletion of not only tissue reserves of iron but also a decrease in the level of its transport form, and the disappearance of sideroblasts in the bone marrow. Characteristic is the preservation of hemoglobin fund (no anemia). Peripheral blood values are normal or slightly changed.

   There is a decrease in serum iron levels, and an increase in the total iron-binding capacity of serum, while red blood cells can be microcytic and hypochromic. The clinical picture is due to trophic disorders and manifestations of sideropenic syndrome.
3. Iron deficiency anemia is characterized by a more pronounced depletion of tissue reserves of iron and mechanisms to compensate for its deficiency, deviation from the norm of blood parameters, and clinical manifestations of sideropenic, general anemic, visceral syndromes and secondary immunodeficiency syndrome.

According to Sim et al. (2019), iron deficiency is observed in about 15–35% of female and 5–11% of male athletes. Other sources point to an even higher percentage of athletes with iron deficiency (up to 50% in women and up to 30% in men) (Koehler et al., 2011, Tan et al., 2012).

The most specific laboratory marker of iron deficiency is the serum ferritin content in the blood (Clénin et al., 2015). In their work, Nabhan et al. (2020) recommend using criteria based on threshold values of serum ferritin for detecting iron deficiency in athletes. The following distribution of ferritin threshold values in the blood allows us to divide athletes by their content into four groups:

1. feritin < 12 μg· l^{-1}. It is characterized by the depletion of iron stores in the bone marrow. It is used as the lower limit by laboratories, defining iron–deficiency anemia (the third stage of iron depletion).
2. < 20 μg· l^{-1} indicates latent iron deficiency (the second stage of iron depletion).
3. < 35 μg· l^{-1} indicates prelatent iron deficiency (the first stage of iron depletion).
4. < 50 μg· l^{-1} corresponds to the normal recommended threshold for men. Also, this threshold is recommended as a minimum level for training athletes for high-altitude training.

In turn, when assessing the presence of iron deficiency in athletes, it is important to note that Cook et al. (1992) note that the boundary optimal level of serum ferritin is not less than 45 μg· l^{-1}. Similar recommendations apply to athletes of both male and female sex (over 15 years old). In many scientific publications, ferritin values below 35 μg· l^{-1} are the minimum threshold for detecting iron deficiency in athletes and a recommendation for treatment with iron medications (Govus et al., 2015, Custer et al., 1995, WHO, 2020).

Summing up all the above, the minimum content of ferritin in the blood is 35 μg· l^{-1}, below which the appointment of iron medications for correction of iron deficiency and 45–50 μg· l^{-1} is recommended, as a minimum optimal level for athletes.

Because in sports of the highest achievements, the requirements for the athlete's body are especially high, the presence of iron deficiency becomes an even greater problem. It can have serious consequences, including an increased risk of injury, a slowdown in the recovery processes after physical exertion, a decrease in immunity, and a significant decrease in the performance and effectiveness of the athlete (Sim et al., 2019). It is equally important to consider that in many cases, iron deficiency in athletes can exist without the manifestation of anemia and have a latent flow. These highlight the necessity for conducting detailed studies on ferritin content for diagnosing iron deficiency states in highly trained athletes.

The purpose of the study

Research the content of ferritin and other indicators of iron metabolism in the blood of qualified athletes specializing in various sports in order to identify iron deficiency conditions.

Material and methods

Subjects

The study, which was conducted on the basis of the State Scientific Research Institute of Physical Culture and Sports (Kyiv, Ukraine), involved 159 qualified athletes, including 98 men and 61 women (Table 1). The average age of athletes – men 23,67 ± 4,10 years, women 22,59 ± 6,37 years.

Table 1. Number of athletes participating in the study by sport (n = 159)

Sport	Men (n = 98)	Women (n = 61)
Track and field athletics	23	44
Freestyle wrestling	8	7
Modern pentathlon	15	–
Beach volleyball	4	2
Canoeing	8	–
Rowing	3	–
Boxing	25	8
Greco-Roman wrestling	12	–

The anthropometric characteristics of athletes are presented in Table 2 (Table 2).

Table 2. Athletes' anthropometric indicators ($\bar{x} \pm \sigma$; n = 159)

Indicators	Men (n = 98)	Women (n = 61)
Height, cm	180,91 ± 9,72	171,63 ± 8,40
Body weight, kg	106,28 ± 4,65	76,09 ± 17,11
Body fat, %	25,04 ± 3,64	20,53 ± 6,61
Fat-free mass, kg	85,92 ± 20,96	59,63 ± 9,35

Ethics

The research was conducted following the basic bioethical norms of the Declaration of Helsinki of the World Medical Association on Ethical Principles of Scientific and Medical Research, as amended (2000, as amended in 2008), the Universal Declaration on Bioethics and Human Rights (1997), and the Council of Europe Convention on Human Rights and Biomedicine (1997). Each study participant provided written informed consent to participate in the study.

Laboratory research

The concentration of hemoglobin, the number of red blood cells, and the level of hematocrit were determined in the peripheral blood of athletes on the hematological analyzer «Erma–210» (Japan). Ferritin concentration and iron content were determined in serum using a ChemWell enzyme-linked immunosorbent analyzer (Awareness Technology, USA) using AccuBind ELISA test systems (Monobind Inc., USA) and reagent kits from Pointe Scientific Inc (USA).

Blood was taken in the morning on an empty stomach. Blood samples were taken from the ulnar vein. Their subsequent processing was carried out in accordance with the manufacturer's instructions.

Statistical analysis

All statistical analyses were performed using «Microsoft Excel 2016». The following statistical parameters were determined: mean ($\bar{x}$), standard deviation (σ), and interquartile range (IQR) to determine the distribution of ferritin in the blood of athletes in order to compare the results with studies by other authors.

Results

The World Health Organization (WHO) defines the diagnosis of iron-deficiency anemia based on the threshold values of hemoglobin content in the blood. For men, these levels are at least 130 g· l^{-1}, and for nonpregnant women – at least 120 g· l^{-1} (WHO, 2020, Hasan et al., 2022). As can be seen from the data presented in Table 3, the average hemoglobin content in both men and women is above the lower limit of the norm, indicating the absence of iron deficiency anemia in athletes of both sexes (Table 3). The number of red blood cells and the level of hematocrit are also within the normal range, which is 4,0–5,5· 10^{-12}/l for male athletes; for women – 3,7–4,7 10^{-12}/l (red blood cells) and a hematocrit content of 40–52% for men; for women 37–47%.

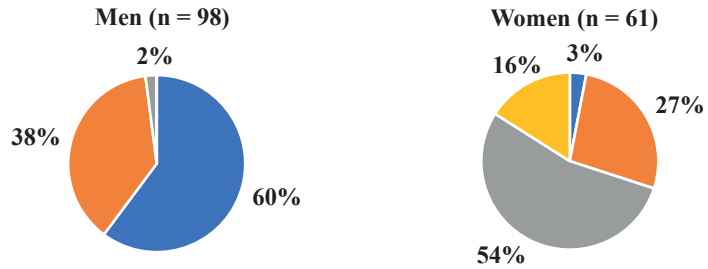
We found that the average concentration of ferritin in serum in men is 88,86 μg· l^{-1} (interquartile range 34–130 μg· l^{-1}), which is the norm for men. However, in women, the average ferritin content is an average of 27,83 μg· l^{-1} (interquartile range 11,23–44,4 μg· l^{-1}), which is classified by Nabhan et al. (2020) the stage of prelatent iron deficiency (first stage of iron depletion). In addition, this value of the average ferritin content is one of the signs

of prelatent iron deficiency according to the classification proposed by Peeling et al. (2007), in which there is hemoglobin content > 115 g· l^{-1}, and ferritin content > 35 μg· l^{-1}.

Table 3. Athletes` blood indicators ($\bar{x}$ ± σ; n = 159)

Indicators	Men (n = 98)	Women (n = 61)
Hemoglobin, g· l^{-1}	152,82 ± 8,74	132,41 ± 6,73
Red blood cells,· 10^{-12}/l	5,34 ± 0,27	4,64 ± 0,22
Hematocrit, %	47,34 ± 3,25	41,74 ± 2,01
Iron, μmol· l^{-1}	30,38 ± 13.56	22,61 ± 6,75

For a more detailed analysis of the ferritin content in the athletes' blood, we divided them into groups according to the classification Nabhan et al. (2020), based on the distribution of blood ferritin threshold values (Figure 1).



Note. Ferritin content, μg· l^{-1} (> 50 35–50 20–35 < 20)

Figure 1. Distribution of athletes (percentage) by blood ferritin content (n = 159)

As can be seen from the data in Figure 1, a significant number of male athletes (60% of 98 athletes) have a ferritin content of more than 50 μg· l^{-1}, and 38% – from 35 to 50 μg· l^{-1}. Such ferritin levels are considered normal values for the general population. Only 2% of male athletes have a ferritin content below 35 μg· l^{-1}.

Among women, the highest percentage (54% of 61 athletes) are those with a ferritin content of 20 to 35 μg· l^{-1}. In turn, 16% (10 athletes) have a ferritin content of less than 20 μg· l^{-1}. These data suggest that most female athletes (70%) have a prelatent or latent iron deficiency.

Serum iron content in both men and women is within the normal range (Table 3). Normally, the iron content in blood serum is 11,6–30,4 μmol· l^{-1} for men and women 8,9–30,4 μmol· l^{-1}, respectively.

Discussion

Our study aimed to determine the content of ferritin and some other indicators of iron metabolism in the blood of qualified athletes specializing in various sports in order to identify iron deficiency conditions. The absence of iron deficiency in the athlete's body is important because iron deficiency can have significant consequences for the athlete, which will lead to a decrease in performance and effectiveness (Sim et al., 2019). It was found that as a result of a lack of iron reserves, the body's ability to transfer oxygen to working muscles decreases. A close relationship between iron content, hemoglobin concentration, maximum oxygen consumption, and aerobic exercise

performance was also found (Nabhan et al., 2020, Chatard, 1999). It is important to note that iron deficiency even without anemia reduces the effectiveness of exercise (DellaValle & Haas, 2011, DellaValle & Haas, 2012).

As a result of our study, athletes of both sexes have no signs of iron deficiency anemia. Almost all male athletes' ferritin values are within the normal range, indicating the absence of iron deficiency. Meanwhile, the majority of women have either prelatent or latent iron deficiency (70% out of 61 female athletes). The results of our study are consistent with the results of a study carried out by Jack et al. (2023), in which it was found that approximately 68% of ballet dancers suffered from iron deficiency. In addition, the work of Disilvestro et al. (2020) revealed an even greater percentage of women actively engaged in healthy running, who have an iron deficiency. Almost all female athletes, with the exception of 2 of 39, had a ferritin content below 35 μg· l^{-1}, which was proposed, according to their classification, as stage 1 of iron deficiency in athletes (ferritin content was 15–35 μg· l^{-1}). The results of our research and other authors (Disilvestro et al., 2020, Jack et al., 2023, Husarova & Vdovenko, 2023) indicate the presence of a serious problem of iron deficiency conditions among female athletes and require appropriate recommendations for the treatment and prevention of iron deficiency conditions.

In order to compare the results of our studies with the works of other authors, we used data from Nabhan et al. (2020), which are based on the distribution of athletes by blood ferritin content. The above authors in their work determined that in male athletes the average ferritin content was 74,0 μg· l^{-1} (interquartile range 45,5–112,0 μg· l^{-1}), in female athletes 33,0 μg· l^{-1} (interquartile range 30,7–51,3 μg· l^{-1}). In turn, the following average values were characteristic for the general population according to Custer et al. (1995): for men aged 20–24 years – 90,2 μg· l^{-1} (interquartile range 58,6–131,0 μg· l^{-1}); age 24–28 years – 105 μg· l^{-1} (76,9–172 μg· l^{-1}). For women (20–24 years) – 31,8 μg· l^{-1} (interquartile range 18,6–52,3 μg· l^{-1}) and aged 24–28 years – 38,8 μg· l^{-1} (22,5–63,4 μg· l^{-1}).

As a result of our study, in which we divided athletes into groups depending on sex and according to the threshold values of ferritin content (12, 20, 35 and 50 μg· l^{-1}), it was found that the average concentration of ferritin in the blood of male athletes is 88,86 μg· l^{-1} (interquartile range 34–130 μg· l^{-1}), in women – 27,83 μg· l^{-1} (interquartile range 11,23–44,4 μg· l^{-1}). The data we obtained on male athletes differ from the values of the general population of men and are slightly higher than the data of athletes obtained by Nabhan et al. (2020). In turn, the average value of ferritin in female athletes is lower and differs both from the data of the general population of women and from the data of the results of studies conducted among athletes, which were described above.

Following a detailed analysis of the ferritin content distribution, it was found that only 2% of male athletes had ferritin values less than 35 μg·l^{-1}, and there were no athletes with ferritin values less than 20 μg·l^{-1}. In turn, the studies of Nabhan et al. (2020) observed a decrease in ferritin content of less than 35 μg· l^{-1} in 15% of athletes and below 20 μg· l^{-1} – 3%. That is, the data we obtained indicate a smaller percentage of athletes (only 2%) who require correction of iron deficiency.

In our studies, 16% of female athletes were found to have ferritin values less than 20 μg·l^{-1} and 54% had values less than 35 μg·l^{-1}. Consequently, 70% of female athletes have a prelatent or latent iron deficiency. According to the above authors, female athletes also had a significant prevalence of iron deficiency (in 23% of qualified athletes, the ferritin content was lower than 20 μg· l^{-1} and 52% – less than 35 μg· l^{-1}). The data of our study coincide with the percentage of women with a ferritin content of less than 35 μg· l^{-1}, but we found a slightly lower percentage of women with a ferritin content of > 20 μg· l^{-1} compared to the data of Nabhan et al. (2020). Discrepancies can be due to many factors, such as the various sports that were included in the study, the geographical features of the conduct (country), climatic conditions, nutritional characteristics, the presence of medical aspects, etc.

Despite the differences in the average values of ferritin content compared to the results of previous studies in sports (Disilvestro et al., 2020, Nabhan et al., 2020, Custer et al., 1995), the data obtained by us fully confirm the fact of the problem of iron deficiency in athletes and the need for routine screening to detect not only iron deficiency anemia, but also a hidden iron deficiency in the body (prelatent and latent stages of iron deficiency).

Athletes are recommended to undergo screening for the detection of iron-deficiency states and prevention of anemia twice a year (Clénin et al., 2015). Researchers agree, despite many blood parameters, that for the routine clinical evaluation of iron deficiency anemia in sports, it is enough to determine the following indicators: hemoglobin concentration, ferritin, and transferrin saturation (Clénin et al., 2015, Peeling et al., 2007).

It is extremely important to note that the minimum threshold for ferritin content in the blood of athletes is recommended values not lower than 45–50 $\mu g \cdot l^{-1}$ (Cook et al., 1992). Athletes with lower serum ferritin levels need to pay special attention to maintaining an optimal level of iron in the body (Govus et al., 2015, Nielsen & Nachtigal, 1998, Solberg & Reikvam, 2023). This is possible by identifying and eliminating the causes leading to its deficiency and/or adjusting the diet. After eliminating the factors that cause iron deficiency, recovery of optimal iron levels can be achieved through a balanced diet, which includes increased consumption of foods high in iron (Vdovenko et al., 2015).

Practical recommendations for correcting the diet of athletes:

1. Increase the content of products with high iron content. The main sources of iron are precisely products of animal origin (liver pork, chicken, veal, meat, poultry, kidneys, etc.);
2. Foods with high levels of phytin, such as cereals and flour products, are recommended to be combined with products rich in vitamin C (berries, citrus fruits, kiwi, etc.);
3. Exclude from the diet foods rich in phytates (instant oatmeal, nuts, seeds, whole grain bread, etc.);
4. Remove from the diet tea and coffee;
5. Do not eat at the same time foods containing iron and foods high in calcium, copper, and magnesium.

If athletes have iron deficiency, a doctor's consultation is mandatory regarding additional iron supplementation. According to the recommendation of the British Society of Gastroenterology (Snook et al., 2021), traditional oral iron salts (ferrous sulfate, ferrous gluconate, and ferrous fumarate) are inexpensive, effective, safe, and readily available—and they remain the standard therapies for iron deficiency anemia. The recommended standard daily therapeutic dose of elemental iron is 100–200 mg. Traditionally oral iron salts were taken as a split dose, two or three times a day (Snook et al., 2021, Liberal et al., 2020).

Conclusions

1. As a result of the study iron deficiency anemia was not detected in subjects of both genders. Nevertheless, a significant number of female athletes (70%) have a hidden (prelatent and latent stages) iron deficiency.
2. It was found that 54% of women and 2% of men have prelatent iron deficiency. In turn, 16% of athletes have latent iron deficiency, which requires appropriate recommendations for treatment and prevention.
3. The results of our studies confirm the presence of the problem of iron deficiency in athletes and indicate the importance of identifying not only iron deficiency anemia but also hidden iron deficiency in order to timely ensure effective treatment and prevention.

Prospects for further research

The presence of iron deficiency in athletes requires further detailed scientific research in representatives of various sports, taking into account a variety of possible factors in order to increase the effectiveness of training and competitive activity of athletes.

References

Al-Naseem, A., Sallam, A., Choudhury, S., & Thachil, J. (2021). Iron deficiency without anaemia: a diagnosis that matters. *Clinical Medicine*, *21*(2), 107–113. https://doi.org/10.7861/clinmed.2020-0582

Alaunyte, I., Stojceska, V., & Plunkett, A. (2015). Iron and the female athlete: a review of dietary treatment methods for improving iron status and exercise performance. *Journal of the International Society of Sports Nutrition*, *12*(1). https://doi.org/10.1186/s12970-015-0099-2

Chatard, J.-C., Mujika, I., Guy, C., & Lacour, J.-R. (1999). Anaemia and iron deficiency in athletes. *Sports Medicine*, *27*(4), 229–240. https://doi.org/10.2165/00007256-199927040-00003

Clénin, G., Cordes, M., Huber, A., Schumacher, Y., Noack, P., Scales, J., & Kriemler, S. (2015). Iron deficiency in sports – definition, influence on performance and therapy. *Swiss Medical Weekly*. https://doi.org/10.4414/smw.2015.14196

Coates, A., Mountjoy, M., & Burr, J. (2017). Incidence of Iron Deficiency and Iron Deficient Anemia in Elite Runners and Triathletes. *Clinical Journal of Sport Medicine*, *27*(5), 493–498. https://doi.org/10.1097/jsm.0000000000000390

Cook, J. D., Baynes, R. D., & Skikne, B. S. (1992). Iron Deficiency and the Measurement of Iron Status. *Nutrition Research Reviews*, *5*(1), 198–202. https://doi.org/10.1079/nrr19920014

Custer, E., Finch, C. A., Sobel, R. E., & Zettner, A. (1995). Population norms for serum ferritin. *PubMed*, *126*(1), 88–94.

Damian, M.-T., Vulturar, R., Login, C. C., Damian, L., Chis, A., & Bojan, A. (2021). Anemia in Sports: A Narrative Review. *Life*, *11*(9), 987. https://doi.org/10.3390/life11090987

DellaValle, D. M., & Haas, J. D. (2011). Impact of Iron Depletion Without Anemia on Performance in Trained Endurance Athletes at the Beginning of a Training Season: A Study of Female Collegiate Rowers. *International Journal of Sport Nutrition and Exercise Metabolism*, *21*(6), 501–506. https://doi.org/10.1123/ijsnem.21.6.501

DellaValle, D. M., & Haas, J. D. (2012). Iron Status Is Associated with Endurance Performance and Training in Female Rowers. *Medicine & Science in Sports & Exercise*, *44*(8), 1552–1559. https://doi.org/10.1249/mss.0b013e3182517ceb

DiSilvestro, R. A., Joseph, E., Diehl, J., & Swain, C. B. (2020). Ferritin readings in young adult, female university student recreational runners. *Journal of Trace Elements in Medicine and Biology*, *62*, 126617. https://doi.org/10.1016/j.jtemb.2020.126617

Govus, A. D., Garvican-Lewis, L. A., Abbiss, C. R., Peeling, P., & Gore, C. J. (2015). Pre-Altitude Serum Ferritin Levels and Daily Oral Iron Supplement Dose Mediate Iron Parameter and Hemoglobin Mass Responses to Altitude Exposure. *PLOS ONE*, *10*(8), e0135120. https://doi.org/10.1371/journal.pone.0135120

Hasan, M. M., Soares Magalhaes, R., Garnett, S., Fatima, Y., Tariqujjaman, M., Pervin, S., Ahmed, S., & Mamun, A. (2022). Anaemia in women of reproductive age in low- and middle-income countries: progress towards the 2025 global nutrition target. *Bulletin of the World Health Organization*, *100*(03), 196–204. https://doi.org/10.2471/blt.20.280180

Husarova, A. M., & Vdovenko, N. V. (2023a). *Laboratory diagnostics of iron deficiency in track and field athletes. У Physical culture and sports in the european educational space*. Baltija Publishing. https://doi.org/10.30525/978-9934-26-337-8-14

Jack, M. L., Sumrall, K., Nasrallah, C., Stuckey, D. C., & Vijay Jotwani. (2023). Analysis of Serum Ferritin Levels in a Group of Elite Ballet Dancers. *Journal of Dance Medicine & Science : Official Publication of the International Association for Dance Medicine & Scienc*e, *27*(3), 160–166. https://doi.org/10.1177/1089313x231178089

Kassebaum, N. J., Jasrasaria, R., Naghavi, M., Wulf, S. K., Johns, N., Lozano, R., Regan, M., Weatherall, D., Chou, D. P., Eisele, T. P., Flaxman, S. R., Pullan, R. L., Brooker, S. J., & Murray, C. J. L. (2014). A systematic analysis of global anemia burden from 1990 to 2010. *Blood*, *123*(5), 615–624. https://doi.org/10.1182/blood-2013-06-508325

Koehler, K., Braun, H., Achtzehn, S., Hildebrand, U., Predel, H.-G., Mester, J., & Schänzer, W. (2011). Iron status in elite young athletes: gender-dependent influences of diet and exercise. *European Journal of Applied Physiology*, *112*(2), 513–523. https://doi.org/10.1007/s00421-011-2002-4

Liberal, Â., Pinela, J., Vívar-Quintana, A. M., Ferreira, I. C. F. R., & Barros, L. (2020). Fighting iron-deficiency anemia: Innovations in food fortificants and biofortification strategies. *Foods*, *9*(12), 1871. https://doi.org/10.3390/foods9121871

Nabhan, D., Bielko, S., Sinex, J. A., Surhoff, K., Moreau, W. J., Schumacher, Y. O., Bahr, R., & Chapman, R. F. (2020). Serum ferritin distribution in elite athletes. *Journal of Science and Medicine in Sport*, *23*(6), 554–558. https://doi.org/10.1016/j.jsams.2019.12.027

Nielsen, P., & Nachtigall, D. (1998). Iron Supplementation in Athletes. *Sports Medicine*, *26*(4), 207–216. https://doi.org/10.2165/00007256-199826040-00001

Peeling, P., Blee, T., Goodman, C., Dawson, B., Claydon, G., Beilby, J., & Prins, A. (2007). Effect of iron injections on aerobic-exercise performance of iron-depleted female athletes. I*nternational Journal of Sport Nutrition and Exercise Metabolism*, *17*(3), 221–231. https://doi.org/10.1123/ijsnem.17.3.221

Sim, M., Garvican-Lewis, L. A., Cox, G. R., Govus, A., McKay, A. K. A., Stellingwerff, T., & Peeling, P. (2019). Iron considerations for the athlete: a narrative review. *European Journal of Applied Physiology*, *119*(7), 1463–1478. https://doi.org/10.1007/s00421-019-04157-y

Snook, J., Bhala, N., Beales, I. L. P., Cannings, D., Kightley, C., Logan, R. P., Pritchard, D. M., Sidhu, R., Surgenor, S., Thomas, W., Verma, A. M., & Goddard, A. F. (2021). British Society of Gastroenterology guidelines for the management of iron deficiency anaemia in adults. *Gut, gutjn*l—2021–325210. https://doi.org/10.1136/gutjnl-2021-325210

Solberg, A., & Reikvam, H. (2023). Iron Status and Physical Performance in Athletes. *Life (Basel, Switzerland)*, *13*(10), 2007. https://doi.org/10.3390/life13102007

Tan, D., Dawson, B., & Peeling, P. (2012). Hemolytic Effects of a Football-Specific Training Session in Elite Female Players. *International Journal of Sports Physiology and Performance*, *7*(3), 271–276. https://doi.org/10.1123/ijspp.7.3.271

Vdovenko, N. V., Ivanova, A. M., & Loshkarova, I. A. (2015). Practical recommendations concerning prevention and correction of iron deficit in athletes. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports*, *19*(1), 12–16. https://doi.org/10.15561/18189172.2015.0103

World Health Organization. (2020*). WHO guideline on use of ferritin concentrations to assess iron status in populations*. World Health Organization.

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THERMAL TOLERANCE CAN BE MAINTAINED AND ENHANCED BY PASSIVE, POST-EXERCISE INTERMITTENT HEAT EXPOSURE FOLLOWING HEAT ACCLIMATION IN A MILITARY CONTEXT

Edward Tom Ashworth[A, B, C, D]

Sports Performance Research Institute New Zealand, Auckland University of Technology, New Zealand
ORCID: 0000-0001-9147-6116 | e-mail: edward.ashworth@sydney.edu.au

James David Cotter[A, D]

School of Physical Education, University of Otago, New Zealand
ORCID: 0000-0002-6014-9865

Andrew Edward Kilding[A, D]

Sports Performance Research Institute New Zealand, Auckland University of Technology, New Zealand
ORCID: 0000-0002-5334-8831

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

Abstract Military personnel are required to operate in hot environments upon short notice. To preserve performance an elevated thermal tolerance could be maintained prior to deployment using heat acclimation (HA) followed by intermittent heat exposure (IHE). In a randomised manner, 19 participants completed 5 d of passive, post-exercise HA in either sauna or hot-water immersion (HWI) followed by 19 d of decay, or IHE every 2–3 days. A heat-stress test involving walking for 1 h in 33°C, 75% humidity in military dress was conducted before HA, after HA, and following the decay or IHE period. Following HA, performance was unaffected, while mean rectal temperature (↓0.3°C), and mean heart rate reduced (↓8 bpm). Following the decay period, performance reduced in the decay group (↓2.6 min) while no change was seen with IHE. IHE saw mean rectal temperature continued to decrease (↓0.1°C) while sweat rate increased (↑0.1 L.h-1), changes not seen in the decay group. These findings showed HA to induce beneficial thermoregulatory adaptations that could be enhanced by IHE in a manner that can be practicably implemented within groups that need to deploy into hot environments at short notice.

Key words: thermoregulation, heat acclimation, military medicine, cardiovascular, intermittent heat exposure

Background

Military units are predisposed to heat illnesses due to restrictive clothing that limits heat loss (Havenith, 1999), carried loads that adds to heat production (Knapik, 1997), and mission objectives that prevent behavioural adaptations, which are exacerbated when work occurs within hot or humid environments. Furthermore, an inability

to access or rely upon cooling methods means mitigation strategies that occur prior to deployment are desirable (Ashworth et al., 2020). Previously we adapted modern HA techniques to provide meaningful physiological changes relating to performance in only 5 days (Ashworth et al., 2022). These strategies utilised saunas and hot-water immersion as methods that do not require specialised facilities or interfere with other training objectives, and had previously shown beneficial physiological adaptations (Heathcote et al., 2018; Zurawlew et al., 2016).

However, military deployment notice can be as short as 12 h and therefore implementing a multiweek HA strategy is challenging, and more efficient strategies are required. One technique that could reduce the timeframe is intermittent heat exposure (IHE), whereby periodical exposure to heat could provide sufficient stimuli to prevent the decay of adaptations (Pryor et al., 2019; Taylor, 2000). When used following a HA programme, a single active exercising IHE session every 5 d can sustain beneficial adaptations in heart rate and core temperature (Pryor et al., 2019). If adaptations can be sustained by periodic exposure to heat, it may be possible to establish and maintain an elevated baseline thermal tolerance within an individual for a prolonged period. By raising the thermal tolerance of a military unit, it is conceivable that if rapid deployment was required military personnel could depart upon request with minimal effects on performance and safety. Furthermore, achieving this with passive heat exposures would minimise the impact on other training objectives, and be more feasible for military cohorts. To investigate this concept, the aim of the current study was to determine the effects of passive, post-exercise IHE as method to retain beneficial physiological adaptations and performance to the heat in a military context.

Methods

Experimental Design and Overview

Each participant completed an initial short-term HA programme using post-exercise, passive HA using either sauna (SAU) or hot-water immersion (HWI), as detailed below. Following HA, participants from each of these conditions were randomised into decay (DEC) or intermittent heat exposure (IHE) groups, with four subgroups: sauna decay (DEC_{SAU}), sauna IHE (IHE_{SAU}), HWI decay (DEC_{HWI}) and HWI IHE (IHE_{HWI}). Those in the IHE groups completed additional HA sessions every 2-3 d over an 18 d period involving exercise and passive, post-exercise heat exposure, while DEC groups completed the exercise component only. Heat-stress tests (HSTs) simulating a 1 h pack march, were conducted in hot-humid conditions (33°C, 75% relative humidity) to assess performance before (pre-HA HST) and after initial HA (post-HA HST), as well as following the 18 d decay and IHE period (post IHE HST).

Participants

Nineteen recreationally active participants took part in the experiment (age 31.7 ±9.8 years, body mass 82.7 ±14.4 kg, $\dot{V}O_2$peak 52.6 ±6.1 $mL.min^{-1}.kg^{-1}$), split into an IHE group of ten and a decay group of nine. Fifteen participants had previously completed a structured HA programme as part of another study (Ashworth et al., 2022) which had concluded at least 6 wk prior, allowing for adequate decay of beneficial adaptations (Ashley et al., 2015), while four were new participants. All participants provided informed consent prior to participation in line with the *Declaration of Helsinki* and institutional ethics approval (AUT Ethics Committee, 18/195).

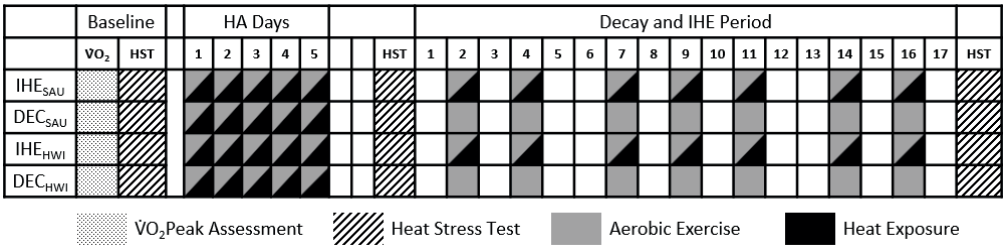

Figure 1. Schematical illustration of the experimental time scale. Each group completed baseline $\dot{V}O_2$ and heatstress tests (HSTs) participants. Within 2-7 d participants began a 5 d heat acclimation (HA) programme using passive, post exercise heating in either sauna (SAU) or hot-water immersion (HWI). A second HST was completed 3 d after completion of the HA programme, followed immediately by either a decay (DEC) or intermittent heat exposure (IHE) period. During this time the IHE group completed heat exposures as per the initial HA every 2-3 d, while the DEC group completed the exercise component only. After ~18 d all participants completed a final HST.

$\dot{V}O_2$Peak Assessment

Each participant completed a preliminary $\dot{V}O_2$peak aerobic assessment in temperate conditions on a motorised treadmill (Pulsar® 3p, h/p/cosmos, Germany), analysed with a calibrated metabolic system (Trueone 2400, Parvo Medicks, Utah, USA). Starting at 7 $km.h^{-1}$ intensity was increased by 1 $km.h^{-1}$ every 3 min, to a maximum of 15 $km.h^{-1}$ after which the gradient was increased in 1% increments. When the respiratory exchange ratio (RER) exceeded 1.00 stages were shortened to 1 min and continued until voluntary termination. All participants exceeded the minimum $\dot{V}O_2$peak of 40 $ml.kg^{-1}.min^{-1}$ required for entry into the study.

HeatStress Tests

Three HSTs were completed as per Figure 1. Each HST was completed at the same time of day by each participant, who avoided strenuous activity and limited alcohol and caffeine consumption for the 24 h preceding each HST. Each HST was carried out in an environmental chamber (Design Environmental, Simultech Australia, Australia), set to 33°C and 75% relative humidity (absolute humidity = 14 $g.m^3$). Following 10 min of seated rest in the chamber participants walked on a motorised treadmill at 5 $km.h^1$ at 1% incline for 1 h, while wearing standard militaryissue longsleeved shirt, trousers, helmet, body armour, a backpack, and their own shoes (full ensemble = 20.6 ±0.7 kg). After 1 h treadmill gradient increased 1% every minute (up to a maximum of 15%) until voluntary termination, 20 min elapsed, or upon reaching ethical limits of core temperature (> 39.5°C) or heart rate (> 95% age-predicted max for 10 s (Tanaka et al., 2001). Fluid consumption was permitted *ad libitum* up to a maximum of 2 L, as per military rations.

Temperature Measures

Core body temperature was recorded rectally, using a flexible thermistor (Hinco Instruments, Australia) inserted 12 cm beyond the anal sphincter. Skin temperature was measured using thermistors placed on the chest,

bicep, thigh and calf on the righthand side of the body and secured with surgical tape (3M Micropore Tape, 3M, New Zealand). Core and skin temperature were logged at 1 Hz (SQ2020, Grant Instruments, Cambridge, UK).

Mean skin temperature was calculated using the following formula (Ramanathan, 1964):

$$T_{Sk} = 0.3T_{Chest} + 0.3T_{Bicep} + 0.2T_{Thigh} + 0.2T_{Calf}$$

Averages over 10 min periods were used for analysis, while 1 min averages of sitting and at the end of steady-state walking were used for resting and end-exercise values, respectively.

Cardiovascular Measures

Cardiac frequency was measured using a 3lead electrocardiogram (Tango+, SunTech Medical, North Carolina), with values recorded at 15 min intervals after a baseline measure was taken while seated inside the chamber. Resting and end-exercise heart rate values were obtained after 5 min of seated rest and after 55 min of walking, respectively.

Sweat Rate

Wholebody sweat rate was estimated using pre and postexercise seminude body mass, corrected for fluid consumption (*(semi-nude weight change + fluid consumption) ÷ walking time*) (Buono et al., 2009). To calculate unevaporated sweat rate weight was measured immediately prior to and immediately following entry and exit from the heat chamber in full dress (*(semi-nude weight change – fully dressed weight change) ÷ walking time*) (Amos et al., 2000).

Hydration Measures

Prior to, and immediately following each trial, participants provided a urine sample that was analysed for urine specific gravity (USG) using a refractometer (Atago, Japan).

Initial Heat Acclimation Protocol

Participants completed post-exercise, passive HA sessions on five consecutive days. Each session comprised of 40 min continuous aerobic exercise, followed by up to 40 min of either sauna or HWI.

Exercise

Upon arrival at the laboratory (19.2 ±0.5 °C, 62.8 ±2.2% RH) participants were weighed and had their auditory canal temperature measured. Exercise was conducted either on a graded treadmill or a stationary cycling ergometer, according to participant preference. Exercise was performed for 40 min at an individually prescribed intensity equivalent to their first ventilation threshold (V-slope method, (Shimizu et al., 1991)), calculated from the initial $\dot{V}O_2$peak assessment. Upon cessation of exercise, weight and auditory canal temperature were measured before participants were transferred to the sauna or HWI facility.

PostExercise Heating

Postexercise, passive heating was conducted either by sitting in a custom-built sauna (~70°C, 20% RH) or mid-sternum immersion in hotwater (~40°C) in a hot tub (Hot Spring, New Zealand). Prior to HWI participants were required to rinse off in warm water (<5 s). Auditory canal temperature was taken immediately preceding heat exposure, while baseline pulse, taken at the wrist was assessed upon exposure to the heat. During each heat exposure participants could drink up to 1 L of water *ad libitum.* Participants could terminate the session at any time but were requested to remain in the sauna or HWI for as long as they felt comfortable, up to 40 min. Measures were repeated every 10 min during the postexercise heating. Auditory canal temperature was taken every 10 min in the HWI, but this was not possible in the sauna where it was taken immediately upon exiting. A final set of measures were also taken if participants terminated the session early, if meaningful time (>2 min) had passed since the last measurement. Participants and drink bottles were then weighed to indicate fluid consumption and for calculation of sweat rate.

Intermittent Heat Exposure

Participants in either IHE group continued to complete HA sessions as per the initial heat acclimation protocol every 2–3 d for 18 d (Figure 1). Sessions were conducted identically to those during the initial HA protocol.

Decay

Participants in either DEC group continued to complete the exercise component of each HA session every 2–3 d for 18 d but received no heat exposure.

Statistical Analysis

Data from both sauna and HWI were pooled together for both DEC and IHE groups to improve statistical power due to the premature termination data collection due to COVID-19. The treatment of these groups as providing similar effects is warranted, based on previous research in this area (Ashworth et al., 2022), whilst these differences are also briefly compared within this manuscript.

All analyses were conducted in R version 3.6.1 (R foundation for Statistical Computing, Vienna, Austria) using the lme4 and emmeans packages. Analyses produced estimated means, standard deviations, confidence intervals and p-values, which were adjusted using the Holm correction for multiple comparisons where appropriate. Absolute data are reported as estimated mean ±standard deviation (SD), while changes are reported as estimated mean change with a 95% confidence interval (i.e., HWI: ↓2 min, [-3, -1], p = 0.003 indicates a 2-minute reduction in the hot-water immersion condition that is significant, with a 95% confidence interval between a 1- or 3-minute reduction). Statistical analysis was split into four phases: 1) The primary analysis evaluated differences between pre-HA or post-HA and post-IHE HSTs for each group (DEC and IHE), and between preHA and postHA for each condition (SAU and HWI). A mixed model ANVOA was run for each variable within the specified comparison with fixed effects of pre-post and group, along with the interaction between the two, and a random effect of participant. Estimated means were calculated and used to obtain post-HA to post-IHE differences in each group: DEC or IHE. A significant interaction between group and pre-post was used to determine a difference between the groups. 2) Analyses of the change in variables during heat exposure across the HA and IHE period were conducted. Each

variable was entered into a mixed model ANOVA with session and time (if appropriate) entered as fixed effects and participant entered as the random effect. ANOVAs were run for each condition, as well as compared between conditions by entering condition as an additional fixed effect. 3) A secondary analysis evaluated differences between conditions within a group (i.e. SAU vs HWI within IHE), a mixed model ANOVA was run within that group, with fixed effects of condition and pre-post as well as their interaction. If the interaction was significant, it was deemed that a difference in the change between the conditions existed. Estimated means were calculated and used to obtain differences between conditions in each group (i.e. DEC_{SAU} vs DEC_{HWI}).

Results

Post-IHE HSTs were conducted an average of 19 ± 3 d following the post-HA HST, with all participants completing all sessions at 2-3 d intervals. Participants in both IHE groups averaged 7.0 IHE sessions, while those in DEC averaged 7.5 sessions.

Heat Acclimation Sessions

During the HA period heating exposure time was not statistically different between conditions (SAU: 27.8 ±7.6 min; HWI: 30.9 ±8.9 min; SAU vs HWI: p = 0.052), and was found to increase only in the HWI condition (SAU: ↑0.5 min, 95% CI [–0.5, 1.5], p = 0.360; HWI: ↑0.7 min, [0.0, 0.1], p = 0.032; HWI vs SAU: p = 0.684). Heart rate reduced significantly between sessions in the sauna condition, but tended to increase during HWI (SAU: ↓2 $b.min^{-1}$, [-3, -1], p<.001; HWI: ↑1 $b.min^{-1}$, [0, 3], p = 0.074; SAU vs HWI: p = 0.001). No changes in sweat rate were seen in either group (both p > 0.262), while fluid consumption increased in the HWI condition only (SAU: No change (NC), [0.00, 0.01], p = 0.782; HWI: ↑0.05 L, [0.00, 0.10], p = 0.013; SAU vs HWI: p = 0.074). Tympanic temperature across sessions was found to reduce in sauna, but not HWI (SAU: ↓0.2°C, [–0.3, –0.1], p = 0.001; HWI: NC, [–0.2, 0.2], p = 0.636; SAU vs HWI: p = 0.323).

Intermittent Heat Exposure Sessions

During IHE sessions, exposure time was significantly longer in the HWI than the sauna (SAU: 29.9 ±7.3 min; HWI: 36.6 ±5.7 min; SAU vs HWI: p < 0.001), although exposure time in the sauna increased across the IHE period (SAU: ↑0.8 min, [0.1, 1.6], p = 0.029; HWI: NC, [–0.02, 0.03], p = 0.867). No changes were observed in either condition for sweat rate (both p > 0.223), heart rate (both p > 0.244) or auditory canal temperature (both p > 0.245), although fluid consumption increased significantly more in the sauna condition (SAU: ↑0.04 L, [0.01, 0.07], p = 0.028; HWI: ↑0.02 L, [–0.03, 0.07], p = 0.360; SAU vs HWI: p = 0.039).

Heat-Stress Tests

Performance

Three participants (1 DEC_{HWI}, 1 IHE_{HWI} and 1 DEC_{SAU}) reached the 20-min ethical limit in each HST they completed and therefore were excluded from analyses of performance.

There was a tendency for improved time to exhaustion in SAU though differences between conditions were not statistically significant across the initial HA period (SAU: ↑3.9 min, 95% CI [–0.1, 7.5], p = 0.071; HWI: ↑3.3 min, [–0.8, 7.4], p = 0.105; Table 1). Following the decay and IHE period a significant reduction was seen in DEC compared to the post-HA HST (DEC: ↓2.6 min, [–5.1, –0.1], p = 0.038; IHE: ↑0.1 min, [2.2, 2.5], p = 0.898; Figure 2). When compared to the pre-HA HST both DEC and IHE groups tended to increase, but this did not reach statistical significance (DEC: ↑2.2 min, [–0.4, 4.8], p = 0.056; IHE: ↑2.3 min, [–0.1, 4.6], p = 0.056).

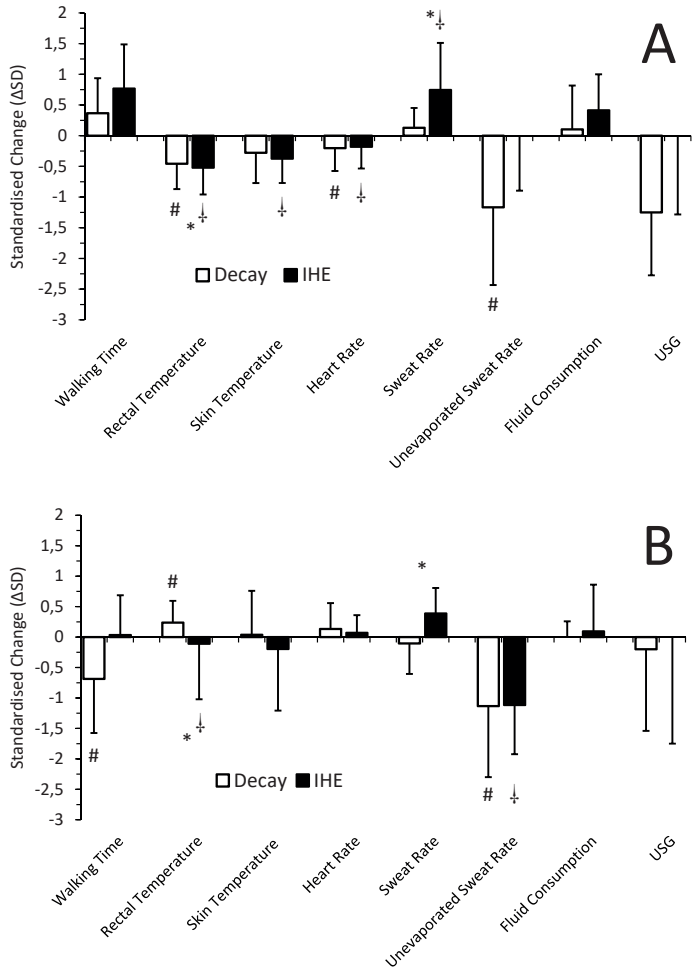

Figure 2. Changes in physiological variables following 19 d of decay or passive, post-exercise intermittent heat exposure (IHE) following an initial 5 d passive, post-exercise heat acclimation (HA) programme. Data are displayed as change from pre-HA values (A) and change from post-HA values (B). Variables are plotted as a function of the standard deviation (SD) of the baseline measures (i.e. (post-IHE – preHA) / $SD_{pre\text{-}HA}$). All data are displayed as mean ± SD. # $p < 0.05$ between baseline and decay value, ⸸ $p < 0.05$ between baseline and IHE value, * $p < 0.05$ between change in groups.

Physiological Variables

Across the intervention, rectal temperature was significantly lowered following both sauna and HWI HA (SAU: ↓0.3°C, [–0.4, –0.2], $p < 0.001$; HWI: ↓0.2°C, [–0.3, 0.1], $p < 0.001$; Figure 3). During the decay and IHE period a significant difference was observed between groups ($p < 0.001$) as the DEC group increased rectal temperature, while the IHE group which continued to reduce (DEC: ↑0.1°C, [0.1, 0.2], $p < 0.001$; IHE: ↓0.1°C, [–0.1, 0.0], $p = 0.001$; Table 1). However, when compared to the pre-HA HST, both groups had significantly lower rectal temperature (DEC: ↓0.1°C, [–0.2, –0.1], $p < 0.001$; IHE: ↓0.2°C, [–0.3, –0.2], $p < 0.001$), which was reduced significantly more in the

IHE group (DEC vs HWI: p = 0.048; Table 1). Although no difference was found between conditions within the IHE group (IHE_{SAU} vs IHE_{HWI}: p = 0.587), there was a significant difference between conditions within the DEC group, with DEC_{HWI} providing a larger reduction in rectal temperature (DEC_{SAU}: ↓0.1°C, [–0.2, 0.0], p < 0.001; DEC_{HWI}: ↓0.3 °C, [–0.5, –0.2], p < 0.001; DEC_{SAU} vs DEC_{HWI}: p = 0.005). No differences were observed in the rate of rise in rectal temperature after HA (both p > 0.327), or between either the pre- or post-HA and the post-IHE HSTs for DEC and IHE groups (all p > 0.127; Table 1).

Skin temperature was reduced following HA in the sauna condition only (SAU: ↓0.3°C, [–0.5, 0.2], p < 0.001; HWI: no change (NC), [–0.2, 0.3], p = 0.667; Table 1). No significant differences were detected between the post-HA and post-IHE HSTs in either DEC or IHE groups (DEC: NC, [–0.1, 0.2], p = 0.841; IHE: ↓0.1°C, [–0.3, 0.0], p = 0.079; Table 1). Compared to the pre-HA HST, both DEC and IHE groups tended towards a reduction in skin temperature although this was significant only in the IHE group, with no difference between groups (DEC: ↓0.1°C, [–0.3, 0.0], p = 0.072; IHE: ↓0.3°C, [–0.4, –0.1], p < 0.001; DEC vs IHE: p = 0.182). While the pre-HA to post-IHE HST comparison showed no difference between conditions in the DEC group (p = 0.536), within the IHE group there was a significant reduction in skin temperature in the IHE_{SAU} group, although this did not differ from the IHE_{HWI} group (IHE_{SAU}: ↓0.4 °C, [–0.6, –0.1], p < 0.001; IHE_{HWI}: ↓0.2°C, [–0.4, 0.1], p = 0.112; IHE_{SAU} vs IHE_{HWI}: p = 0.211).

Heart rate significantly reduced in both conditions following the initial HA period, with a greater decline following sauna HA (SAU: ↓11 b.min^{-1}, [–15, –7], p < 0.001; HWI: ↓5 b.min^{-1}, [–10, –1], p = 0.008; SAU vs HWI: p = 0.033; Table 1). Over the decay and IHE period no changes were observed in either group (both p > 0.172), with both groups remaining significantly lower than the pre-HA HST (DEC: ↓6 b.min^{-1}, [11, –2], p=.005; IHE: ↓5 b.min^{-1}, [-9, -1], p = 0.010; DEC vs IHE: p = 0.653; Table 1).

Table 1. Changes in physiological variables during heat-stress tests at baseline (pre-HA), following a 5 d HA programme (post-HA) and following either decay (DEC) or intermittent heat exposure (IHE) following the HA period. Pre- and post-HA values are displayed as mean ± SD, while the pre-post differences are displayed as mean change, with 95% confidence intervals.

			Change from Post-Test	
Variable	Pre-HA	Post-HA	DEC	IHE
Time to Exhaustion (min)	8.8 ±4.7	12.42 ±4.6	↓3.4 (–6.4, 0.4) $^{\beta}$	↑0.1 (–2.5, 2.8) †
Rectal Temperature (°C)				
Average	37.6 ±0.3	37.3 ±0.3*	↑0.1 (0.1, 0.2) $^{\alpha, \beta}$	↓0.1 (–0.1, 0.0) $^{\alpha, \beta, \dagger}$
Resting	37.1 ±0.4	36.9 ±0.4*	↑0.2 (0.0, 0.3) $^{\alpha}$	↓0.1 (–0.2, 0.0) $^{\alpha, \beta, \dagger}$
End-Exercise	38.1 ±0.4	37.8 ±0.4*	↑0.1 (–0.1, 0.3) $^{\beta}$	↓0.1 (–0.2, 0.0) $^{\beta, \dagger}$
Slope (°C.h^{-1})	1.3 ±0.3	1.3 ±0.3	NC (–0.2, 0.2)	NC (–0.2, 0.2)
Skin Temperature (°C)				
Average	35.8 ±0.4	35.6 ±0.3*	NC (–0.1, 0.2)	↓0.1 (0.3, 0.0) $^{\alpha}$
Resting	34.4 ±0.6	34.3 ±0.6	↑0.2 (–0.2, 0.6)	↓0.1 (–0.4, 0.3)
End-Exercise	36.4 ±0.4	36.3 ±0.4*	↓0.1 (–0.3, 0.1)	↓0.2 (–0.4, 0.0) $^{\alpha}$
Heart Rate (b.min^{-1})				
Average	107 ±13	99 ±13*	↑3 (–1, 7) $^{\alpha}$	↑3 (0, 7) $^{\alpha}$
Resting	71 ±9	65 ±9*	↑4 (–3, 10)	↑3 (–3, 9)
End-Exercise	132 ±17	120 ±17*	↑3 (–4, 9) $^{\alpha}$	↑3 (–4, 9) $^{\alpha}$
Sweat Rate (L.h^{-1})	1.1 ±0.3	1.2 ±0.3	NC (–0.2, 0.1)	↑0.1 (0.0, 0.3) $^{\alpha, \dagger}$
Unevaporated Sweat Rate (L.h^{-1})	0.6 ±0.4	0.8 ±0.4	↓0.3 (–0.6, –0.1) $^{\alpha, \beta}$	↓0.3 (–0.5, -0.1) $^{\beta}$
Fluid Consumption (L)	0.9 ±0.5	1.0 ±0.5	NC (–0.2, 0.2)	NC (–0.2, 0.2)
USG Pre	1.017 ±0.007	1.014 ±0.007	↑0.002 (–0.004, 0.009)	↑0.004 (–0.002, 0.010)
USG Post	1.019 ±0.007	1.015 ±0.007	↑0.002 (–0.005, 0.009)	↑0.004 (–0.003, 0.011)

*indicates p < 0.05 between pre- and post-HA HSTs, $^{\alpha}$ indicates p < 0.05 between pre-HA and post-IHE HST, $^{\beta}$ indicates p < 0.05 between post-HA and post-IHE HST, † indicates p < 0.05 between the change in Decay and IHE.

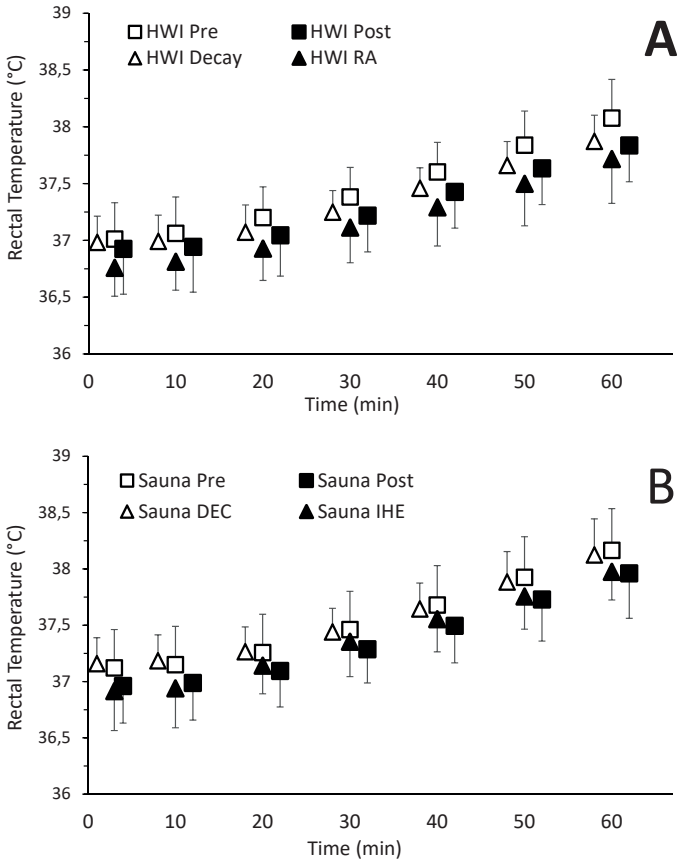

Figure 3. Changes in rectal temperature across a heat stress test (HST) conducted pre- and post-heat acclimation as well as following a period of decay or intermittent heat exposure in both hot-water immersion (HWI) (A), and sauna (B). Data are displayed as mean ±SD. Data are offset from 10-min time points for clarity.

Sweat rate was unchanged following HA in either condition (both $p > 0.206$; Table 1, Figure 4). Furthermore, sweat rate was not significantly changed following the decay and IHE period despite a tendency to increase in the IHE group that was significantly different to the change in the DEC group (DEC: NC, [–0.2, 0.1], $p = 0.507$; IHE: ↑0.1 $L.h^{-1}$, [0.0, 0.3], $p = 0.053$; DEC vs IHE: $p = 0.045$; Table 1). When compared to the pre-test, the IHE group had a significantly elevated sweat rate (Figure 4) that had increased significantly more than in the DEC group (DEC: NC, [–0.2, 0.2], $p = 0.620$; IHE: ↑0.3 $L.h^{-1}$, [0.1, 0.5], $p = 0.002$; DEC vs IHE: $p = 0.026$).

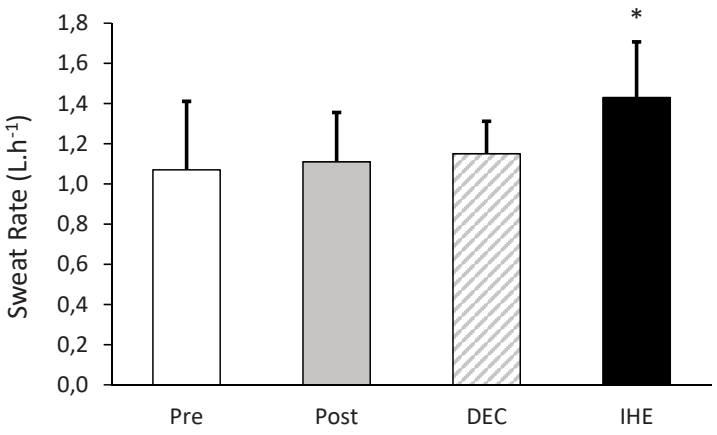

Figure 4. Changes in sweat rate over the course of HA and the subsequent decay (DEC) and intermittent heat exposure (IHE) period. Aggregated means of both groups (DEC and IHE) are used for pre and post, with the DEC and IHE results shown as projected changed based on the within group changes from post-HA to post-IHE HSTs. *p > 0.05 compared to pre-HA HST.

No changes in unevaporated sweat rate were seen over HA (both p > 0.476). Following the decay and IHE period, significant reductions in unevaporated sweat rate were seen in both groups, with no difference between groups (DEC: ↓0.3 L.h^{-1}, [–0.6, –0.1], p = 0.005; IHE: ↓0.3 L.h^{-1}, [–0.5, –0.1], p = 0.006; DEC vs IHE: p = 0.675; Table 1). When compared to the pre-HA HST, only the DEC group had a significant reduction, although this did not reach statistical significance compared to the IHE group (DEC: ↓0.4 L.h^{-1}, [–0.7, 0.0], p = 0.040; IHE: NC, [–0.3, 0.3], p = 0.982; DEC vs IHE: p = 0.077).

Fluid consumption did not change following HA (both p > 0.469) or following the decay and IHE period in either group compared to both the post-HA HST (both p = 1.000), and the pre-HA HST (both p > 0.126; Table 1). Similarly, no differences were seen in hydration as assessed by USG either before or after the HST over the course of HA (> 0.266), between post-HA and post-IHE HSTs (all p > 0.205) or between pre-HA and post-IHE HSTs (all p > 0.152; Table 1).

Discussion

The primary aim of this study was to determine the effectiveness of intermittent, passive, postexercise heat exposure (IHE) to maintain beneficial heat adaptations obtained from a prior shortterm HA programme. The present results indicate that IHE can maintain several important physiological parameters that aid physical performance and safety when operating in hot environments, and potentially enhance adaptations to resemble those seen in longer HA protocols.

Physical performance typically improves by 7% following short-term (<7 d) HA (Tyler et al., 2016), although time to exhaustion or capacity tests typically induce greater improvements (Scoon et al., 2007; Tyler et al., 2016). In the present study the initial 5 d HA saw no improvement in time to exhaustion although improvements have previously been seen in identical (Ashworth et al., 2022), and near identical protocols (Zurawlew et al., 2016). During the decay period following the initial HA, performance declined as expected, as underlying physiological

adaptations diminish (Daanen et al., 2018). However, following IHE performance was maintained (Table 1; Figure 2), suggesting the continued heat stimulus retained thermoregulatory adaptations. Conversely, Gerrett et al. (2021) found performance reduced following a 5 d re-acclimation period (after 10 d controlled hyperthermia HA) compared to post-HA, despite maintaining other physiological adaptations. For military units with short deployment notice and concerns with heat-induced performance impairments, IHE provides a promising strategy that could maintain physical performance during operations in a hot climate.

Reductions in core temperature are typically observed across HA (Faulkner, 2016; Heathcote et al., 2018; Tyler et al., 2016), consistent with the reduced rectal temperature at rest, at end-exercise, and on average following short-term HA in both conditions during the present study (Figure 3). The DEC group saw rectal temperature return to pre-HA values at a rate of ~1.7%.d^{-1} (Table 1; Figures 2 and 3), slower than typically reported (Daanen et al., 2018). Indeed, other protocols have found 2 wk of decay returned rectal temperature to pre-HA values (Garrett et al., 2009; Poirier et al., 2015), whereas after 18 d of decay in the current study, rectal temperature was still reduced relative to pre-HA (Figure 2A), potentially due to the continuation of aerobic exercise (Aoyagi et al., 1998; Cohen & Gisolfi, 1982).

With IHE, the initial reduction in rectal temperature was augmented, further increasing the capacity for heat gain to improve performance and safety (Aoyagi et al., 1994). Previous attempts to reobtain core temperature adaptations from a prior HA programme have returned differing results. Following 26 d of decay Weller et al. (2007) found a single day of re-acclimation (100 min walking at ~5.5 km.h^{-1} in 32°C, 18% RH) returned rectal temperature to post-HA values, while Ashley et al. (Ashley et al., 2015) suggested 4 d of re-acclimation after 2 wk of decay, and 5 d following 4 wk of decay, was required to restore rectal temperature. However, both these studies returned core temperature to the value seen post-HA, whereas in the current study (with IHE every 2–3 d) rectal temperature reduced beyond that of the initial HA programme (Figure 2B). Kirby et al. (2021) looked at IHE to sustain heat adaptations following post-exercise sauna HA, and found that three, 30-min sessions a week caused an additional 0.1°C reduction in rectal temperature, on top of the –0.2°C reduction seen during the initial HA, nearly identical to that seen in the current study. When mixed mode IHE (90-240 min in 40°C, 40% RH) was used every 5 d for 25 d following HA by Pryor et al. (2019) rectal temperature remained significantly lower than pre-HA, but no further decreases were observed. The greater volume of heat exposure used by Pryor et al. (2019) during HA may have induced stronger physiological adaptations that, may require smaller or less frequent stimuli to maintain (Moss et al., 2019). Indeed, the HAinduced change in end-exercise rectal temperature seen by Pryor et al. was ~3 times greater than that seen in the current study. While the minimal heat exposure (~2.5 h) used in the current study during the 5 d HA may have limited the upregulation of adaptive mechanisms (Moss et al., 2019), during the IHE period the additional exposure likely progressed these adaptations, causing changes typically associated with longer HA programmes. For groups planning to use IHE to maintain heat adaptations for a prolonged period, a shortterm HA programme may be sufficient.

One reason core temperature reduced with IHE might be the increase in sweat rate compared to preHA (Figure 4). IHE has previously been unable to maintain sweat rate adaptations, despite increasing over the initial HA period (Pryor et al., 2019). Sweat rate adaptations typically take over two weeks to occur (Poirier et al., 2015), so this finding is likely a result of the accumulated volume of heat exposure (Fox et al., 1964). The increased sweat rate following IHE helps regulate body temperature by facilitating evaporative heat loss (Amos et al., 2000). Achieving

an increase in sweat rate using IHE following HA provides a much more efficient and practical means to obtaining heat adaptations in military personnel.

Central adaptations, such as heart rate, are among the fastest heat adaptations to occur (Faulkner et al., 2016), and were seen across HA. However, following the decay and IHE period both groups significantly increased heart rate, with no differences between the groups (Table 1, Figure 2B). While end-exercise heart rate decayed slower (1.3%.d^{-1}) than that seen in the literature (~2.3%.d^{-1}) (Daanen et al., 2018), this could be explained by the exercise component alone maintaining cardiovascular adaptations (Aoyagi et al., 1998). However, the similar rate of decay in the IHE group was unexpected. The lack of change observed here contrasts with that shown by Pryor et al. (Pryor et al., 2019) where post-exercise heart rate in the IHE group was ~14% lower than in the decay group. As most participants reached the time-limit placed on IHE sessions, the adaptive stimuli were likely lessened, preventing further adaptation (Gibson et al., 2019). A method that ensures constant progression of heat strain in passive heating protocols would be valuable both for the implementation of IHE, as well as longer passive, post-exercise heating programmes available in the current literature (Heathcote et al., 2018).

Conclusions

In summary, application of IHE to maintain adaptations from a previously conducted HA programme appears a beneficial approach, and in some cases may even enhance desirable physiological adaptations for performing in the heat. For military groups that may receive minimal notice before being deployed to a hot environment, a short passive, post-exercise HA programme, that is minimally disruptive to training and other commitments, may provide a basis for maintenance of elevated thermal tolerance, thereby improving operational performance and safety upon arrival in hot environments. Further research would better elucidate differences between passive heating modalities when used as IHE.

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Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

References

Amos, D., Hansen, R., Lau, W. M., & Michalski, J. T. (2000). Physiological and cognitive performance of soldiers conducting routine patrol and reconnaissance operations in the tropics. *Mil Med*, *165*(12), 961–966. https://doi.org/10.1093/milmed/165.12.961

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1994). Effects of training and acclimation on heat tolerance in exercising men wearing protective clothing. *Eur J Appl Physiol Occup Physiol*, *68*(3), 234–245. https://doi.org/10.1080/001401398187071

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1998). Effects of endurance training and heat acclimation on psychological strain in exercising men wearing protective clothing. *Ergonomics*, *41*(3), 328–357. https://doi.org/10.1080/001401398187071

Ashley, C. D., Ferron, J., & Bernard, T. E. (2015). Loss of heat acclimation and time to re-establish acclimation. *J Occup Environ Hyg*, *12*(5), 302–308. https://doi.org/10.1080/15459624.2014.987387

Ashworth, E., Cotter, J., & Kilding, A. (2022). Post-exercise, passive heat acclimation with sauna or hot-water immersion provide comparable adaptations to performance in the heat in a military context. *Ergonomics*, *66*(1), 49-60. https://doi.org/10.1080/00140139.2022.2058096

Ashworth, E. T., Cotter, J. D., & Kilding, A. E. (2020). Methods for improving thermal tolerance in military personnel prior to deployment. *Military Medical Research*, *7*(1), 58. https://doi.org/10.1186/s40779-020-00287-z

Buono, M. J., Numan, T. R., Claros, R. M., Brodine, S. K., & Kolkhorst, F. W. (2009). Is active sweating during heat acclimation required for improvements in peripheral sweat gland function? *Am J Physiol Regul Integr Comp Physiol*, *297*(4), R1082-1085. https://doi.org/10.1152/ajpregu.00253.2009

Cohen, J. S., & Gisolfi, C. V. (1982). Effects of interval training on work-heat tolerance of young women. *Med Sci Sports Exerc*, *14*(1), 46–52. http://doi.org/10.1249/00005768-198201000-00009

Daanen, H. A. M., Racinais, S., & Periard, J. D. (2018). Heat Acclimation Decay and Re-Induction: A Systematic Review and Meta-Analysis. *Sports Medicine*, *Online*, 1–22. https://doi.org/10.1007/s40279-017-0808-x

Faulkner, S. J. L., Mears, S., Esliger, D., Sanderson, P. (2016). *Review of Human Acclimatisation to Heat or Cold.*

Fox, R. H., Goldsmith, R., Hampton, I. F., & Lewis, H. E. (1964). The Nature of the Increase in Sweating Capacity Produced by Heat Acclimatization. *J Physiol*, *171*, 368–376. https://doi.org/10.1113/jphysiol.1964.sp007382

Garrett, A. T., Goosens, N. G., Rehrer, N. J., Patterson, M. J., & Cotter, J. D. (2009). Induction and decay of short-term heat acclimation. *Eur J Appl Physiol*, *107*(6), 659–670. https://doi.org/10.1007/s00421-009-1182-7

Gerrett, N., Alkemade, P., & Daanen, H. (2021). Heat Reacclimation Using Exercise or Hot Water Immersion. *Med Sci Sports Exerc*, *53*(7), 1517–1528. https://doi.org/10.1249/mss.0000000000002612

Gibson, O. R., James, C. A., Mee, J. A., Willmott, A. G. B., Turner, G., Hayes, M., & Maxwell, N. S. (2019). Heat alleviation strategies for athletic performance: A review and practitioner guidelines [review]. *https://doi.org/10.1080/23328940.2019.1666624*. https://doi.org/KTMP-2019-0025

Havenith, G. (1999). Heat balance when wearing protective clothing. *Ann Occup Hyg*, *43*(5), 289–296. https://doi.org/10.1016/S0003-4878(99)00051-4

Heathcote, S. L., Hassmen, P., Zhou, S., & Stevens, C. J. (2018). Passive Heating: Reviewing Practical Heat Acclimation Strategies for Endurance Athletes. *Front Physiol*, *9*, 1851. https://doi.org/10.3389/fphys.2018.01851

Kirby, N. V., Lucas, S. J. E., Armstrong, O. J., Weaver, S. R., & Lucas, R. A. I. (2021). Intermittent post-exercise sauna bathing improves markers of exercise capacity in hot and temperate conditions in trained middle-distance runners. *European Journal of Applied Physiology*, *121*(2), 621–635. https://doi.org/10.1007/s00421-020-04541-z

Knapik, J. J, Ang, P., Meiselman, H., Johnson, W., Kirk, J., Bensel, C., Hanlon, W. (1997). Soldier Performance and Strenuous Road Marching: Influence of Load Mass and Load Distribution. *Mil Med*, *162*(1), 62–67. https://doi.org/10.1093/milmed/162.1.62

Moss, J. N., Bayne, F. M., Castelli, F., Naughton, M. R., Reeve, T. C., Trangmar, S. J., Mackenzie, R. W. A., & Tyler, C. J. (2019). Short-term isothermic heat acclimation elicits beneficial adaptations but medium-term elicits a more complete adaptation. *Eur J Appl Physiol*. https://doi.org/10.1007/s00421-019-04269-5

Poirier, M. P., Gagnon, D., Friesen, B. J., Hardcastle, S. G., & Kenny, G. P. (2015). Whole-body heat exchange during heat acclimation and its decay. *Med Sci Sports Exerc*, *47*(2), 390–400. https://doi.org/10.1249/mss.0000000000000401

Pryor, J. L., Pryor, R. R., Vandermark, L. W., Adams, E. L., VanScoy, R. M., Casa, D. J., Armstrong, L. E., Lee, E. C., DiStefano, L. J., Anderson, J. M., & Maresh, C. M. (2019). Intermittent exercise-heat exposures and intense physical activity sustain heat acclimation adaptations. *J Sci Med Sport*, *22*(1), 117–122. https://doi.org/10.1016/j.jsams.2018.06.009

Ramanathan, N. (1964). A new weighting system for mean surface temperature of the human body. *J Appl Physiol*, *19*(3), 531–533. https://doi.org/10.1152/jappl.1964.19.3.531

Scoon, G. S., Hopkins, W. G., Mayhew, S., & Cotter, J. D. (2007). Effect of post-exercise sauna bathing on the endurance performance of competitive male runners. *J Sci Med Sport*, *10*(4), 259–262. https://doi.org/10.1016/j.jsams.2006.06.009

Shimizu, M., Myers, J., Buchanan, N., Walsh, D., Kraemer, M., McAuley, P., & Froelicher, V. F. (1991). The ventilatory threshold: method, protocol, and evaluator agreement. *Am Heart J*, *122*(2), 509–516. https://doi.org/10.1016/0002-8703(91)91009-c

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*, *37*(1), 153–156. https://doi.org/10.1016/s0735-1097(00)01054-8

Taylor, N. A. (2000). Principles and Practices of Heat Adaptation. *Journal of the Human-Environment System*, *4*(1), 11–22. https://doi.org/10.1618/jhes.4.11

Tyler, C. J., Reeve, T., Hodges, G. J., & Cheung, S. S. (2016). The Effects of Heat Adaptation on Physiology, Perception and Exercise Performance in the Heat: A Meta-Analysis. *Sports Med*, *46*(11), 1699–1724. https://doi.org/10.1007/s40279-016-0538-5

Weller, A. S., Linnane, D. M., Jonkman, A. G., & Daanen, H. A. (2007). Quantification of the decay and re-induction of heat acclimation in dry-heat following 12 and 26 days without exposure to heat stress. *Eur J Appl Physiol*, *102*(1), 57–66. https://doi.org/10.1007/s00421-007-0563-z

Zurawlew, M. J., Walsh, N. P., Fortes, M. B., & Potter, C. (2016). Post-exercise hot water immersion induces heat acclimation and improves endurance exercise performance in the heat. *Scand J Med Sci Sports*, *26*(7), 745–754. https://doi.org/10.1111/sms.12638

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