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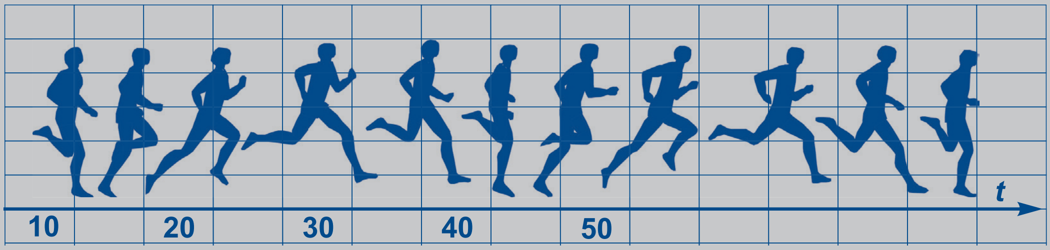

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CORRELATIONS BETWEEN THE DIMENSIONS OF FATIGUE AND THE KICKING PERFORMANCE OF SOCCER PLAYERS DURING PENALTY SHOOTOUTS

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
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Abstract:

Background: Failures in penalty shootouts have often been attributed to various psychological constructs, with minimum attention given to the players' physiological conditions at the time of the shootouts. The purpose of this study was to examine the impact of mitigation on fatigue of soccer players and the effect on their Kicking Performance (KP) during penalty shootouts after 120 minutes of intensive play using General Fatigue (GF), Physical Fatigue (PF), Reduced Activity (RA), Reduced Motivation (RM), and Mental Fatigue (MF) as fatigue proxies. We hypothesized that the levels of the 5 fatigue dimensions would correlate with KP (Kicking Accuracy [KA], Kicking Velocity [KV], and Kicking Quality [KQ]) of the players in the experimental and control groups following the protocol.

Methods: A two-group pre-test/post-test quasi-experimental research design was adopted for this study. Thirty male soccer players with a mean age of 19.17±2.68 years were assessed on fatigue and KP before and after playing soccer for 120 minutes with interventions in the experimental groups. The results were compared among the players and with some international values.

Results: There were statistical correlations between GF and KP (τ_b = .377, p = .041), MF and KP (τ_b = .372, p = .042), as well as the Overall Fatigue (OF) and KP (τ_b = .458, p = .016). There were no statistically significant correlations between all the other variables.

Conclusion: It was determined that extreme fatigue correlates with and affects KP in penalty shootouts after 120 minutes of playing soccer. The study also concluded that adequate and periodic supplementation is important to remedy the effects of GF, MF, and OF to maintain the kicking performance of soccer players during penalty shootouts.

Introduction

Fatigue in sports is a key physiological process that has raised scientific interest for decades. Indeed, early researchers who worked extensively on fatigue considered it to be a limiting factor for athletes' motor and perceptual processing [1-3]. In soccer, factors that cause fatigue in the players include the size of the pitch and the chronic bouts of intermittent high-intensity and long duration of play during a standard 90-minute game [4,5]. Furthermore, [5] reported that players' muscle glycogen stores are reduced by 40%–90% following a standard 90-minute soccer match. It is, therefore, anticipated that when players are subjected to an extra 30 minutes of play, which extends the duration to 120 minutes due to the stalemate of a match during national and international tournaments [5-8], the fatigue levels of players become extreme.

This extreme exhaustion, which impairs players' performance, e.g., their kicks become less effective [9] in a stalemate match through 120 minutes, is again tested by the rules of soccer in a penalty shootout to break ties. However, it is surprising to note that failures in these shootouts have been solely attributed to psychological constructs, including pressure, stress, anxiety, etc., with little attention paid to the functioning of the players' body composition, even though the players' performance is fundamentally physiological.

Studies by [10,11] have confirmed that all kicks are physiological by nature but comprise three (3) dimensions: Kicking Accuracy (KA), Kicking Velocity (KV), and Kicking Quality (KQ). It is, however, unclear whether the extreme fatigue experienced after 120 minutes of play affects all three dimensions of kicking. Additionally, [12] developed the Multidimensional Fatigue Inventory (MFI-20), which spans the five (5) dimensions of fatigue: General Fatigue (GF), Physical Fatigue (PF), Reduced Motivation (RM), Reduced Activity (RA), and Mental Fatigue (MF). It is, again, uncertain whether all the fatigue dimensions individually, or in combination, relate to the KP of soccer players. This unexplored concept of fatigue and the impaired gross motor performance or penalty shooting failures warranted the need to assess the relationships between the two (2) variables. Therefore, the study aimed to examine the impact of fatigue mitigation on soccer players and its effect on their Kicking Performance (KP) during penalty shootouts after 120 minutes of intensive soccer using *General Fatigue (GF), Physical Fatigue (PF)*, *Reduced Activity (RA)*, *Reduced Motivation (RM)*, and *Mental Fatigue (MF)* as fatigue proxies.

We, therefore, hypothesized that the levels of the 5 fatigue dimensions would correlate with the KP of the players in both experimental and control groups following the prescribed protocol.

Materials and Methods

Research Design

A two-group pre-test/post-test quasi-experimental research design was adopted for this study since it is one of the most solid platforms that facilitate cause-and-effect relationships [13-15].

Participants

The total participant pool for this study was men's soccer team players who play in the national tier-one league. Of these, 25 players were regularly selected for national teams or national tier-1 clubs for such tournaments. However, for this study, the population was 30 male field soccer players, allowing for 2 teams of 15 field players each as experimental and control groups.

These players were purposively sampled from premier league teams in Ghana based on the criteria that they were already fit and could be engaged for 120 minutes, had no injuries, were non-diabetic, and did not smoke [6]. Therefore, the players were categorised into 10 Keeper Dependent (KD) and 10 Keeper Independent (KI) players with an extra 5 each serving as substitutes purposively grouped for the study. The design permitted the use of a smaller number of participants for the study [16].

There were discussions between the participants and authors on the confidentiality of information obtained before the commencement of and during the tests. Participants were given instructions and adequate demonstrations of the measurements and procedures before the beginning of the tests. The nature, purpose, and expected outcomes during and after the administration of the tests were also explained to all participants. Those who showed interest signed informed consent forms.

Protocols and Measurements

The measurements for this study were taken pre- and post-protocol in the following phases.

Pretest

Phase 1: The body weights of the participants were measured with Camry ISO 9001 Model digital portable scale (Japan) with a range of 0-120 kg to the nearest 0.1 kg to determine the quantum of bolus as well as the grammage of the intervention to be given to each player before the start of the protocol. The plyers' weights were recorded according to the procedure outlined in [17].

Phase 2: Meals were served to the players, followed by a rest period, after which a high-glycaemic beverage consisting of a 50/50 glucose-fructose electrolyte mix (glucose and red grape extract) [18] was served to the experimental group. The meal was a standardised Ghanaian balanced dish (4g $\cdot$ kg^{-1} of body mass (BM) of carbohydrate (plain rice-62%), fat (oiled stew-25%), and protein (fish-13%) totalling 1470 kJ of energy) [6]. The meals were served around 11:00 a.m., i.e., three hours before a match play or testing [19], allowing time for digestion and assimilation, which is a routine for the players before a competition. Thus, the players remained at rest for approximately 180 minutes before commencing a standardized warm-up (running, active dynamic and passive stretching, and on-the-ball workouts) that preceded the main trial. However, to stabilize the blood glucose levels, especially in the morning of the test (as they would on a match day), the players also ate their regular meals the previous evening and the morning before a match/ the testing.

All the players performed all exercise protocols at the same time of day as they would on a match day to account for the effects of circadian rhythm [20]. Therefore, the players were tested between 14:30 and 17:00. The average temperature of the testing field throughout the data collection period was 33.1±1.2°C, with an average wind speed of 4 km/h.

Phase 3: The blood glucose levels of the participants were taken with the One Touch Select Plus Flex digital portable glucose metre (China) in mmol/litre. The measurements of the glucose levels of the players were taken from fresh capillary whole blood samples obtained from the fingertip before and after the protocol.

Phase 4: The MFI-20, a versatile 5-point scale instrument that seeks to solicit responses on the soccer players' fatigue levels before and after the protocol, was used for the study. The MFI-20 has a 20-item fatigue monitoring scale that evaluates the 5 dimensions of fatigue (GF, PF, RM, RA, and MF) [12]. The instrument is a simple self-administered paper-and-pencil assessment that takes 5 to 10 minutes to complete. The players rated how exhausted they were or not on each item on the scale of 1 ("that is true") to 5 ("no, that is not true") as to the extent to which they agreed or disagreed with the statements posed pre- and post-protocol.

Phase 5: Players' kicking performance (KP) was measured using the following indicators: KA - average distance from the ball entry point to the goal centre, KV - the distance per the average time elapsed from hitting the ball to the point of entry, and KQ - kicking accuracy per the average time elapsed from hitting the ball to the point of entry) [10,11], with a plywood target (122 cm high with a width of 243.5 cm x 243.5 cm) mounted on a wall in the gymnasium, adopted from [21]. The surface was covered with white textured paper, with a black 5 cm bull's-eye placed at the midpoint of the board and paper. A screw was also placed in the middle of the bull's-eye in such a way that a hook at the end of a tape measure fitted over the head of the screw to precisely measure the distance from the bull's eye to the centre of the mark where the ball struck the target. There was another sheet of white paper covered by carbon paper placed behind the original bull's eye paper on the board, such that the striking of the ball left a mark on the underlying white paper. For each new kick, a new sheet of paper-plus-carbon was used. Ten repeated shooting trials per session were performed from a 6.1 metre distance from the target [21].

Penalty kicks from the penalty spot of a standard soccer field and goalpost with a goalkeeper to serve as a distractor were also taken to augment the KP of the players. A Canon EOS 700D digital SLR camera with an EFS 55-250 mm lens mounted on a Samsung tripod was used to take videos of the players performing the penalty kicks for further analysis.

Phase 6: The participants then played 120 minutes of competitive football on a standard FIFA-sized soccer field to induce fatigue and ensure ecological validity. Glucose-fructose electrolyte interventions were given to the players in the experimental group, and water was served as a placebo to the players in the control group, after which the rest of the measurements were taken as follows. The refreshments were administered periodically, i.e., using the [22] water break system for international competitions (30 mins break, 1st half break, 75 th and 90 th-minute breaks).

Post-test

Phase 7: Blood glucose levels of the participants were again measured immediately at the end of the protocol.

Phase 8: The KPs and the MFI-20 measurements, as described in Phases 4 and 5, were then taken to complete the protocol.

Statistical Analysis

IBM SPSS Statistics Data Editor version 26 was used to analyse the data collected. Both descriptive and inferential statistics were used to compute the data obtained for this study. The Kendall's tau-b correlation coefficient was employed to analyse the correlations that existed between fatigue and KP of the players due to the non-normal distribution of the data, as determined by the Shapiro-Wilk test. The alpha level was set at 0.05

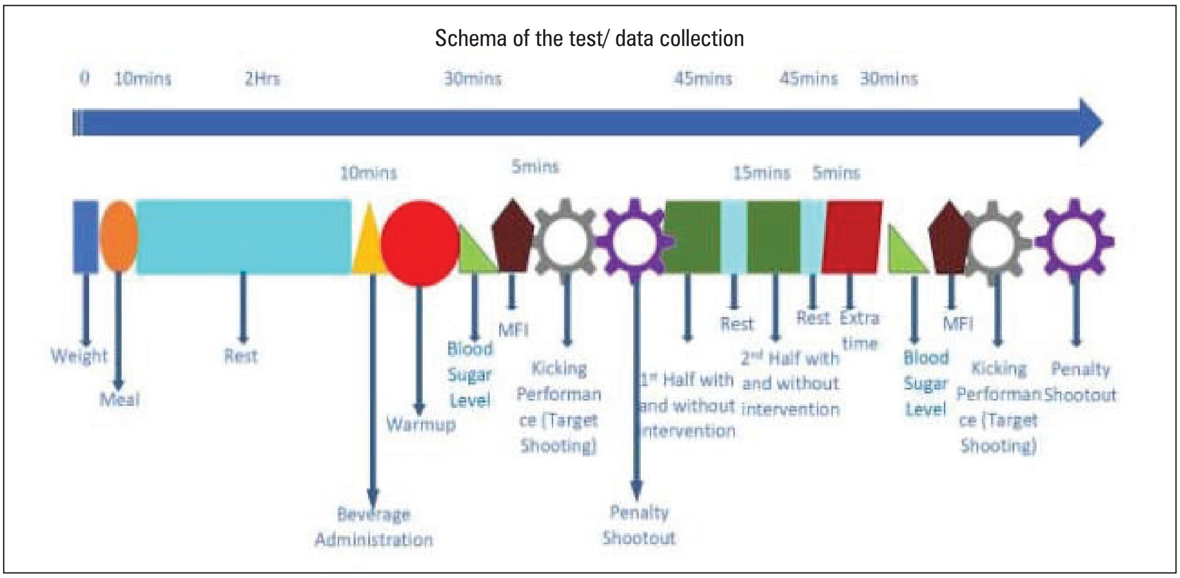

Figure 1. Detailed plan of the test

Results

Table 1 presents the means, standard deviations (SD), and ranges for the ages, weights, heights, and playing experience of the soccer players. These values suggest that the soccer players are youthful and have normal weights, heights, and experience.

Table 1. Demographic characteristics of the players (N=30)

Demographic Characteristic	N	Min.	Max.	Mean	Standard Deviation
Age (year)	30	16.00	27.00	19.17	2.68
Weight (kg)		55.10	86.20	66.09	7.74
Height (m)		1.53	1.85	1.74	0.07
Experience (yrs)		4.00	15.00	8.93	2.57

Source: Field survey (2024).

The soccer players in the study were aged between 16 to 27 years, with a mean of 19.17±2.68 years. The participants weighed between 55.10 kg and 86.20 kg, with a mean weight of 66.09±7.74 kg. The mean height was recorded at 1.74±0.065 m, with a minimum and maximum body height of 1.53 m and 1.85 m, respectively. The average playing experience was 8.93±2.57, with the least experienced player having played for 4 years and the most experienced for 15 years. These players were grouped into experimental (or treatment) and control groups (E = 15, C = 15), which were further subdivided into a regular time treatment group (n =10), a substitute treatment group (n = 5), regular time control (n =10), and substitute control (n = 5).

Table 2. Kendall's tau-b correlation coefficient of participants' fatigue levels and kicking performance

Variable	Kendall's tau-b Correlation Coefficient	p
Pre-test GF vs pre-test KP	-.137	.455
Pre-test PF vs pre-test KP	.281	.126
Pre-test RA vs pre-test KP	.006	.972
Pre-test RM vs pre-test KP	.275	.132
Pre-test MF vs pre-test KP	.233	.205
Post-test GF vs post-test KP	.377	.041* consistent with [23] and [24]
Post-test PF vs post-test KP	.230	.212
Post-test RA vs post-test KP	.162	.397
Post-test RM vs post-test KP	.285	.114
Post-test MF vs post-test KP	.372	.042* consistent with [23] and [24]

Source: Field survey, 2024. *The correlation is significant at the 0.05 level

Table 2 shows the Kendall's tau-b correlation coefficient analysis of the players' various dimensions of fatigue and KP. The results suggested a statistically significant correlation between post-test GF and corresponding KP (τ_b = .377, p = .041) and between post-test MF and its respective KP (τ_b = .372, p = .042), respectively. These results are supported by [23] and [24], as discussed in the following section. No statistically significant were found for the remaining variables.

Table 3. Kendall's tau-b correlation coefficient of participants' overall fatigue levels and kicking performance

Variable	Kendall's tau-b Correlation coefficient	p
Pre-test fatigue vs pre-test KP	.111	.564
Post-test fatigue vs post-test KP	.458	.016 supported by [23] and [24]

Source: Field survey (2024). *The correlation is significant at the 0.05 level

The Kendall's tau-b correlation coefficient results in Table 3 show a statistically significant correlation between post-test fatigue and post-test KP, τ_b = .458, p = .016. However, there was no significant correlation between pre-test fatigue and pre-test KP (τ_b = .111, p = .564).

Discussion

This study investigated the relationships between fatigue and kicking performance (KP) metrics in soccer players, both before and after 120 minutes of competitive play. The following discussion highlights the findings derived from the research. Due to the non-parametric nature of the study, the Kendall's tau-b statistical method was employed to analyse potential correlations between the variables of interest to test the proposed hypothesis. This analysis was conducted on individual variables before evaluating the overall correlation between fatigue and KP.

The results obtained from the Kendall's tau-b analysis, as presented in Table 2, revealed statistically significant correlations between certain dimensions of fatigue and KP. Specifically, a significant correlation was identified between post-test GF and corresponding KP, with a tau-b value of .377 and a p-value of .041, indicating a meaningful relationship. However, the pretest GF and its corresponding KP showed no correlation (τ_b = -.137, p = .455), which suggests that GF resulting from extreme and prolonged loading negatively impacts KP, thereby explaining the observed differences and significant relationships.

Additionally, a noteworthy correlation was found between post-test MF and its corresponding KP, with a tau-b value of .372 and a p-value of .042, further supporting the connection between these variables. It may be inferred that the soccer players experienced mental fatigue as a result of the protocol, thereby establishing the relationship. In contrast, the analysis did not reveal any significant correlations for the other variables examined, suggesting that the relationship between fatigue and KP may be limited to the dimensions of general and mental fatigue.

The examination of the relationship between KP and overall fatigue demonstrated a statistically significant correlation between fatigue levels measured after the test and the corresponding KP results, as evidenced by the Kendall's tau-b correlation coefficient presented in Table 3 ($\tau b = .458$, $p = .016$). Conversely, the analysis revealed no significant correlation between pre-test fatigue levels and pre-test KP ($\tau b = .111$, $p = .564$). As a result, the hypothesis suggesting that the five dimensions of fatigue would exhibit a correlation with KP among players in both groups following the protocol was not rejected, given the statistically significant correlations identified between specific fatigue measures and overall fatigue using the Kendall's tau-b test at the 0.05 significance level. This conclusion is further corroborated by the findings presented in [23], which indicated that maximal ball velocity and kicking performance are significantly affected by fatigue ($F = 7.6$, $p<.001$, $\eta 2 = .46$). Moreover, the assertion of [24] that states that there were significant correlations between the maximal kicking velocity and fatigue index ($r = 0.632$, $p < 0.01$) and sprinting decrement S_{dec} ($r = -0.554$, $p < 0.05$) and between the kicking accuracy and the rating of perceived exertion RPE ($r = -0.506$, $p < 0.05$) fully supports the findings of this study.

Limitations of the Study

The ecological validity of the tests may have been compromised because some aspects of the experiment were laboratory-based and time-consuming, which may have allowed players partial recovery.

Additionally, some participants may have been encouraged to perform better in the post-test due to their experience. Thus, some of the findings may be the consequences of their familiarity with the first performance tests.

Conclusion

The results of this study suggest that KP during penalty shootouts after playing soccer for 120 minutes is significantly correlated with the extreme fatigue of the players. This indicates that fatigue, and thus the physiological condition of players, plays a role in the failures of penalty shooting after 120 minutes of playing. However, appropriate in-game interventions can help preserve KP and potentially minimize these failures.

Practical Implication

Team officials (manager, dietician, nutritionist, etc.) and players engaged in 120 minutes of playing in a soccer competition before a penalty shootout must always mitigate GF and MF through sufficient carbohydrate loading, especially by consuming high-glycaemic beveragse composed of a 50/50 glucose-fructose electrolyte mix (e.g., glucose and red grape extract) starting at the beginning of the match through to the end to sustain performance during the shoutout.

Conflict of Interest: The authors declare that there is no conflict of interest.

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Institutional Review Board Statement: The research was approved by the Ethical Review Board of KNUST (approval number HuSSREC/AP/115/VOL. 1, dated: 30th May 2023).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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CHANGES IN BIOELECTRICAL ACTIVITY OF THE ERECTOR SPINAE MUSCLES OF THE LUMBAR SPINE AFTER DEEP MASSAGE OF THE HAMSTRINGS

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Background: Low back pain is a significant medical and socioeconomic problem. The pain is often caused by abnormal work and increased tension of the erector spinae muscle. Effective pain management has become very popular in recent years. Physiotherapists are increasingly using a holistic concept of human cognition in their therapies, which involves the interdependence and coordination of the entire body.

Methods: The study involved 36 students, each of whom underwent a single session of deep tissue massage of the hamstrings muscles. The Thomayer test was used to assess the flexibility of these muscles, while changes in the bioelectrical activity of the erector spinae muscles were evaluated using the NORAXON EMG device, which took into account the protocol developed for this purpose.

Results: A single session of deep tissue massage of the hamstrings muscles showed statistically significant changes in the results of the Thomayer test. The average bioelectrical activity of the erector spinae muscle in the resting standing position decreased both in the treated and untreated side showing statistically significant changes. During flexion on the treated side, a statistically significant decrease in muscle activity was observed, which was not observed during extension.

Conclusions: Deep tissue massage of the hamstring muscles positively influenced the ability to reach the floor with fingers with straightened knees, which could have resulted from the increased flexibility of the hamstring muscles. This therapy may be an effective complementary form of treatment for trigger points in the hypertonicity of the erector spinae muscle. Researchers who intend to explore this topic are recommended to include control groups in their studies and to implement a series of therapeutic sessions.

Introduction

Low back pain is a significant medical and socio-economic problem as it affects approximately 80% of the general population [1-2]. The pain can manifest in various forms. It may be of neuropathic or nociceptive origin. Both types of pain have their specific characteristics, locations, and description of the pain experienced. Any dysfunction in an anatomical element can lead to painful symptoms in the lumbar spine area, pelvis, and even lower limbs [3]. The pain appearing in the lumbar spine area can have various causes. The contributing factors include dysfunctions of muscles, fascia, ligaments, bone structures, joints, or intervertebral discs [4]. When searching for the causes of pain, the improper functioning of the erector spinae muscles and their increased tension is often emphasized. The appearance of pain in the back muscles along with sensitive points may indicate the presence of myofascial trigger points. These points are painful to palpation and may cause radiating discomfort [5,6]. Effective methods of treating myofascial trigger points have become very popular in recent years [7-10]. Physiotherapists increasingly try to apply a holistic concept of understanding the human body, which assumes the interdependence and coordination of the entire body. However, there is still a lack of research on the effectiveness of treating myofascial trigger points in different areas of the body than those where the painful symptoms occur. The concept of anatomical chains according to Thomas W. Myers suggests looking at and addressing tension problems in muscles more broadly. This researcher combined and expanded on the achievements of many of his predecessors and created a complete map of longitudinal myofascial connections whose analysis allows for a better understanding of how the human body moves and functions. The discovery that muscles not only attach to bones but also connect through connective tissue helps to understand how tensions and contractions within one structure can be transferred to very distant areas of the body [11].

Inspired by this statement, the present study was conducted to investigate whether a deep-tissue massage of hamstring muscles could reduce erector spinae muscle tension.

Material and Methods

Participants

The study involved 36 students, including 21 females (58.3%) and 15 males (41.7%) between the ages of 19 and 26 years (Table 1). The research was conducted in the Functional Diagnostic Laboratory at the Department of Rehabilitation at the Bronisław Czech University of Physical Culture in Krakow (previously: University of Phisical Education in Krakow). Each participant was recruited for the study based on predetermined inclusion and exclusion criteria presented below.
Inclusion criteria:
- written consent to participate in the study,
- age between 19 to 26 years,
- no contraindications to trigger point therapy,
- presence of characteristic symptoms of trigger points in the erector spinae muscle of the lumbar spine.

Exclusion criteria:
- acute muscle damage,
- fractures,
- recent joint injuries,
- local or general sensory disturbances,
- the presence of inflammatory conditions,
- active cancer,
- general contraindications to manual therapy.

Prior to the study, the body height of each participant was measured using a tape measure, and their body mass was measured using a ZEEGMA Gewit scale (Table 1). Height was measured in centimeters (cm) and body mass was measured in kilograms (kg).

Table 1. Characteristics of the study group

	Number	**Age (Mean ± SD)**	**Body height (Mean ± SD)**	**Body weight (Mean ± SD)**
Women	21	(22.04 ± 1.59)	(168.86 ± 6.90)	(61.43 ± 9.55)
Men	15	(22.6 ± 1.70)	(183.27 ± 5.73)	(79.80 ± 10.48)

Research project

After appropriate qualification, the examination began with bilateral palpation of the erector spinae muscle by the therapist in the lumbar region of the spine. The patient was lying prone during the examination. The first task of the therapist was to locate the trigger point on the muscle. The search for the trigger point involved identifying a hypertonic band of the muscle that, when pressed, caused pain and radiation. during the identification of the trigger points, the therapist took into account the areas of their presence described in the literature and the symptoms produced by them [12]. The palpation was performed on the exposed skin of the patient. If trigger points were present on both sides of the patient's body, the therapist selected the side that exhibited greater pain and later applied therapy to these hamstrings. One side was chosen for therapy to determine whether working on the side generating more pain would also affect the other side.

A four-channel electromyography (EMG) device MyoTrace 400 (Noraxon USA Inc.) and the Thomayer test were used to evaluate the effects of the massage. EMG is a measurement tool used to study the electrical signals received from muscles by means of the technique called surface electromyography (sEMG). This technique is a fast and non-invasive method that allows for the analysis and recording of motor unit activity in muscles, and its great advantage is that it does not interfere with the human body, making the whole process painless for participants. The average results are expressed in microvolts (μV), and disposable electrodes are used for the measurement.

Figure 1. Surface electromyography (sEMG) system: Noraxon MyoTrace 400 (source: own materials)

In the present research project, sEMG was used to examine the bioelectrical activity of the erector spinae muscle before and after therapy. During the measurement, the patient was in a standing position. Prior to the measurement, the therapist had to prepare the treatment area by cleaning the patient's skin with salicylic spirit and removing any unnecessary hair from the body. After cleaning the patient's skin, the surface electrodes were placed in the appropriate location. For each participant, 6 disposable Sorimex electrodes were applied on both sides of the spine according to the generally accepted methodology. Two of the electrodes were placed at the L3 level of the erector spinae muscle, while the reference electrode was placed on the upper posterior iliac crest. In order to ensure the uniformity of the measurements and their later analysis for research purposes, a special protocol was created using the MyoResearch Master Edition program. This protocol included a measurement of the 30-second resting muscle tension and function. The movement of the erector spinae muscle was evaluated by flexion and extension of the lumbar spine, with 10 seconds allocated for each movement by the patient. The bioelectrical activity of the muscles was measured twice - before and after the intervention.

Figure 2. The Thomayer test (source: own materials)

The Thomayer test was also used in the study to assess the flexibility of the hamstring muscle group. It also allowed for the evaluation of the mobility of the entire spine during forward bending. The test involves bending forward as far as possible in the sagittal plane with the knees straight. Before performing the test, each participant stepped onto a non-slip step with dimensions of 36m x 28cm x 24cm to avoid the floor limiting the range of motion by touching it with their hands. The distance was measured with a centimeter tape from the edge of the step to the end of the third finger. If the subject was able to reach below the level of the step, the result was recorded as a positive number. If the subject did not reach the level of the step, the result was recorded as a negative number. The Thomayer test was evaluated twice: before and after the intervention.

Intervention

A therapy was performed after measuring the bioelectrical activity of the muscles and the range of motion of the lumbar spine. The intervention consisted of a deep tissue massage of the hamstring muscles on the lower limb on the side where the greater pain of the erector spinae muscles of the lumbar spine was diagnosed. The methodology of the therapy was as follows: the therapist flexed the lower limb of the participant at the knee to 90°, then performed a slow, passive extension at the knee joint, connected with a calm fist work in the direction of the muscle fibers from the lower leg up to the ischial tuberosity. Initially, the semitendinosus and semimembranosus muscles were worked on, followed by the biceps femoris, and finally, the fascia between these muscles. The therapy lasted 5 minutes.

Statistical analysis

Statistical analysis of the study results was performed using Microsoft Excel and Statistica 13. The Shapiro-Wilk test was used to determine the distribution of the analyzed variables. Measurement of the significance of differences for dependent samples was performed using the Student's t-test or Wilcoxon's paired sample test. The significance of statistical differences was determined at $p<0.05$.

Results

After a single deep tissue massage of the hamstring muscles, the mean changes in the Thomayer test results increased statistically significantly by an average of 1.39 cm (Table 2).

Table 2. The effect of a single deep tissue massage session on the flexibility of the hamstring muscles.

CHANGES IN THE Thomayer's test						
Statistical measures		**Arithmetic mean**	**Minimum**	**Maximum**	**Standard deviation**	**p**
Thomayer test (cm)	Before	3.64	-25	20	10.29	0.001*
	After	5.03	-25	23	10.31	

*p<0.05 – statistically significant differences

After the therapy, the average changes in resting bioelectrical activity of the erector spinae muscle decreased. This change was statistically significant ($p<0.05$). The average values of bioelectric activity during flexion decreased and also showed a statistically significant change, while during extension, bioelectric activity showed no significant changes (Table 3).

Table 3. The effect of a single deep tissue massage of the hamstring muscles on the bioelectrical activity of the erector spinae muscle on the treated side.

CHANGES IN THE BIOELECTRICAL ACTIVITY OF THE ERECTOR SPINAE MUSCLE ON THE TREATED SIDE						
Statistical measures		**Arithmetic mean**	**Minimum**	**Maximum**	**Standard deviation**	**p**
Rest (μV)	Before	7.08	2.34	27.30	4.91	0.01*
	After	6.08	2.55	26.80	4.40	
Flexion (μV)	Before	9.15	2.11	62.90	13.02	0.04*
	After	8.58	2.23	45.20	8.73	
Extension (μV)	Before	22.55	7.12	67.60	14.20	0.4
	After	20.95	6.35	69.60	11.75	

*p<0.05 – statistically significant differences

Table 4. The effect of a single deep tissue massage of the hamstring muscles on the bioelectrical activity of the erector spinae muscle on the untreated side.

CHANGES IN THE BIOELECTRICAL ACTIVITY OF THE ERECTOR SPINAE MUSCLE ON THE UNTREATED SIDE						
Statistical measures		Arithmetic average	Minimum	Maximum	Standard deviation	p
Rest (μV)	Before	5.54	1.62	13.20	2.26	0.01*
	After	4.66	2.64	9.42	1.84	
Flexion (μV)	Before	14.08	2.64	68.80	12.26	0.1
	After	14.77	4.14	39.00	9.13	
Extension (μV)	Before	20.18	6.76	44.2	9.32	0.8
	After	20.46	6.19	45.9	9.23	

*$p<0.05$ – statistically significant differences

After treatment in the study group, the mean changes in resting bioelectrical activity on the contralateral side of the erector spinae muscle decreased. This change was statistically significant ($p<0.05$). The mean values of bioelectrical activity during flexion and extension showed no statistically significant changes (Table 4).

Discussion

The contemporary model of physiotherapeutic treatment increasingly focuses on a holistic approach to the patient. According to the assumptions of the Polish rehabilitation model, it should be early, comprehensive, and continuous, and the therapist should try to influence the patient's body as an integral whole [13]. Changes in tension and muscular and fascial restrictions can affect various structures of the human body [14]. Some evidence suggests that muscular tension can be transmitted to adjacent tissues, so tissue restrictions in one part of the body may affect other parts located even in different segments [15]. As Joshi et al. [16] write, there is a relationship between the lumbosacral region, the hamstring tendons, and the entire posterior chain.

Studies conducted by many authors have shown a high percentage of people with myofascial trigger points [17,18]. Wheeler et al. [19] showed that 85% of patients with post-traumatic complaints and about 90% of people with other diseases have trigger points in their bodies. Despite their widespread occurrence, a significant proportion of them remains undiagnosed, which unfortunately leads to a lack of treatment [20]. The problem with diagnosing trigger points lies with the symptoms that also appear in adjacent muscle groups or distant areas of the body, not just the directly affected muscle, which makes it difficult to identify the main source of the problem [21]. Many authors use surface electromyography in addition to palpation to evaluate people with trigger points, which was also used in our previous studies [22-24].

Most authors focus mainly on the impact of their chosen therapy on the site of reported pain [25-28]. An example of such research is the study by Rodrigues et al. [29], who assessed the impact of myofascial release on the elasticity and bioelectrical activity of the erector spinae muscles. They compared superficial and deep myofascial release techniques. To evaluate the therapy, the researchers used the finger-to-floor test and sEMG measurements during flexion and extension of the lumbar spine. Ten students participated in the study, and the therapy was administered twice a week for 40 minutes. After conducting 10 therapy sessions, the authors repeated the finger-to-floor test and sEMG measurements, observing a statistically significant improvement in the test and no differences in the measurements of muscle bioelectrical activity.

In scientific articles, authors are increasingly striving to demonstrate that by working on a different structure within the same chain, one can influence the changes occurring in that part of the body. Studies conducted by Sekiguchi et al. [30] also provided interesting conclusions regarding the influence of individual structures in the human body on each other. The authors examined the relationship between shoulder or elbow joint pain and reduced internal rotation in the hip joint of the stepping leg. They analyzed young baseball players participating in the National Festival of Junior Sports Clubs. The following measurements were taken: range of external and internal rotation in the hip joint, the fingertip-to-floor test, straight leg raise (SLR) test, range of knee flexion, and dynamic postural control using the Star Excursion Balance Test. Of all participants, 16 reported experiencing elbow or shoulder pain during the tournament. The authors observed that a reduced range of internal rotation in the hip joint of the stepping leg was significantly associated with elbow or shoulder pain. The researchers recommended that coaches, athletes, and their clinicians consider the function of the trunk and lower limbs in preventing pain in the shoulder and elbow in the future.

Interesting studies on a similar topic were conducted by Aparicio et al. [31]. The authors assessed the immediate effect of the inhibitory technique on suboccipital muscles by evaluating pain threshold and hamstring muscle length. Seventy participants were recruited for the study, with thirty-six individuals in the intervention group and thirty-four individuals in the placebo group. The pain threshold of trigger points was assessed using a pressure algometer on the semitendinosus, biceps femoris, and adductor magnus muscles before and after the therapy. Hamstring muscle length was evaluated using the finger-to-floor test (SLR), whereas active knee extension was assessed using the hip flexed at 90°. The authors demonstrated that after the therapy was applied in the intervention group, there was an improvement in the results of the muscle length measurements, while the pain threshold increased only in the semitendinosus muscle.

The observed impact of the therapy used in the present study requires confirmation by adding a control group, which constitutes a limitation of our research. It is also important to assess the effectiveness of the therapy not only immediately after its implementation but also in a later period, which was not performed in our study. In future studies, the authors undertaking similar research are recommended to consider these limitations and conduct a series of such therapies for patients.

Conclusions

1. The application of deep tissue massage of the hamstrings positively affected the muscle flexibility in the Thomayer test among the tested individuals.
2. Deep tissue massage of the hamstring muscles can be an effective adjunctive treatment for individuals with the presence of trigger points in the erector spinae muscle of the lumbar spine.
3. Deep tissue massage of the hamstring muscles should be included in physiotherapy programs for patients with trigger points in the erector spinae muscles of the lumbar spine.

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Data availability statement: The data presented in this study are available on request from the corresponding author.

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SUCCESS ORIENTATION AMONG YOUNG PEOPLE PRACTICING MARTIAL ARTS IN DIFFERENT COUNTRIES

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
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Abstract:

Background: The scientific frameworks for this study are the General Theory of Fighting Arts and the holistic Anthropology of Martial Arts. These theories provide definitions and conceptional framework for all combat sports and martial arts (CSMA). The aim of this study was to explain the perception of success in international groups of children and teens practicing various martial arts.

Methods: The Perception of Success Questionnaire (POSQ) was used for this study. 430 young martial artists from Poland, Ukraine, China, Japan, Malaysia, and South Korea were surveyed. The Statistica and LibreOffice Calc software packages were used. Significance was accepted at the level of $\alpha=0.05$.

Results: The following correlations were noted: between the perception of success and gender (r=0.85); between the perception of success and age (r=0.86); between the perception of success and nationality (r=0.65); and between the perception of success and martial arts (r=0.87).

Conclusions: The correlations observed between the perception of success and other variables may suggest that cultural patterns are becoming significantly more uniform in the era of globalization. However, the limited scope of the research and the small size of the groups do not allow for unequivocal generalizations.

Introduction

Perception of success is an important issue in modern coaching and of the psychology of sport, pedagogy, and physical education [1, 2]. It comes from psychology of education with conceptions of task/goal, and success; and from achievement goal theory [3, 4]. There are two types of goal orientation: learning orientation (“Trainees can desire to learn the training content i.e., have high levels of motivation to learn) for two reasons: (a) They see a relationship between their effort and actual learning progress (i.e., expectancy), and (b) the outcomes that can be attained from such progress are valued (i.e., valence)” [5] and performance orientation (“A performance orientation underlies a maladaptive response pattern in which challenges are avoided and is characterized by a tendency to seek to prove oneself in achievement situations, often by completing a task as quickly as possible”) [6]. Both types are parts or manifestations of the motivational processes which affect learning.

The global popularity of various martial arts of Asian origin requires international, multi-centre research. This task is being carried out under auspices of the Division of Pedagogy International Martial Arts and Combat Sports Scientific Society (IMACSSS) and Idokan Poland Association (IPA) Project no. 5/2021-24; 5.1. Cultivation, institutionalisation, and adaptation of martial arts in Europe [7]. The scientific frameworks for this study are the General Theory of Fighting Arts and the holistic Anthropology of Martial Arts [8-10]. These theories provide definitions and conceptual framework all types of combat sports (“Competitive contact sports where two combatants fight each other to gain enough points or to achieve a condition to declare a single winner by means of using certain rules of direct engagement. These rules of engagement and conditions are significantly different from the rules in a simulated contact or combat meant for technically-based challenges, practice, or demonstration in martial arts, typically with the aim of simulating elements of real hand-to-hand combat through kata and self-defence training”) [11 p52] and martial arts (”Extensive systems of codified practices and traditions of combat that are practised for a variety of reasons, including self-defence, competition, physical health and fitness, as well as mental, physical and spiritual development”) [11]. A person practicing CSMA is treated holistically, with their needs and motivations, aspirations and aims, body, mind, and spirit.

For the present research, among the many varieties of combat sports and martial arts (CSMA), the representations of *taekwondo* and *karate*, Malaysian *silat*, and Chinese *wushu* were included. Massively practiced in China, modern sports *wushu* draws on the tradition of the old *kung-fu wushu* [8, 12]. *Karate* and *taekwondo* are also popular today on a global scale. However, *taekwondo* has its specifics. It is practiced as a sport, martial art, self-defense purposes, and for physical education [13, 14]. *Taekwondo* is also a current Olympic discipline. Okinawan, Japanese, and the “new styles created outside the Japanese islands” *karate* differ in their approaches to sport (from affirmation, through tolerating sports competition, to its complete rejection), to traditions (training methods, values and goals) and to curricula (sphere of technical, technical and tactical skills) [15, 16]. Malaysian *silat* (*seni silat*) has yet another specificity, which is somewhat reminiscent of Chinese and Indonesian styles, and it is practiced in its traditional version and as a combat sport reminiscent of *karate* or kickboxing [17, 18]. Current CSMA literature finds that some authors focus on the philosophy of martial arts for explanation of their impact into perception of success, aspirations, and tasks/goals [19-22]. Socio-cultural conditions of the martial arts perception and internalisation of the special ethos are is quite often [23-25].

This study will provide valuable insights into the comparison of different groups (e.g., age groups, genders, skill levels) in terms of similarities or differences in the perception of success in the arts and martial arts. Furthermore, from a scientific and cognitive perspective, this study allows the results to be placed within a broader theoretical context concerning motivation, success, and achievements. Therefore, the problem and aim of this study were to explain the “perception of success” in international groups of children and teenagers practicing various martial arts.

In order to achieve this objective, the following research questions were posed: 1) How does one’s gender affect respondents’ perception of success?; 2) What correlation exists between perception of success by the respondents and their age?; 3) How does one’s nationality affect respondents’ perception of success?; 4) How does the type of CSMA affect respondents’ perception of success?; 5) What is differences in the average values of selected variables between respondents’ perception of success and their gender, ages, nationality, and type of CSMA?

In reference to the presented research questions, the following hypotheses (based on the relevant scientific literature) were formulated: H1) There is at least a strong correlation between the respondents’ answers on the perception of success and their gender, H2) There is at least a strong correlation between perception of success by the respondents and their age, H3) There is at least a strong correlation between perception of success by the respondents and their nationality, H4) There is at least a strong correlation between perception of success by the respondents and the type of martial art or boxing they practice.

Material and Methods

Participants

The actions were conducted not only among practitioners of martial arts but also combat sport. The data were collected in dojos, clubs, and schools, among 430 individuals (aged 5-16) practicing various martial arts disciplines including boxing, *aikido*, *goshinjitsu*, *ju jitsu*, *karate*, *kung fu*, *silat*, *taekwondo*, and *wu shu*. The research was conducted between the years 2022 and 2023 in China, Japan, Malaysia, Ukraine, South Korea, and Poland. Information regarding the martial art or combat sports of the respondents is presented in Table 1.

Table 1. Characteristics of respondents by martial art or combat sport

	China	Japan	Ukraine	Poland	Malaysia	SouthKorea	Total
Boxing	56	0	0	0	0	0	56
Aikido	0	0	3	0	0	0	3
Goshinjitsu	0	0	0	4	0	0	4
JuJitsu	0	0	0	34	0	0	34
Karate	0	61	49	30	0	0	140
KungFu	0	0	0	22	0	0	22
Silat	0	0	0	0	48	0	48
Taekwondo	0	0	0	0	12	64	76
WuShu	47	0	0	0	0	0	47
Total	103	61	52	90	60	64	430

The respondents consisted 56 boxing, 3 *aikido*, 4 *goshinjitsu*, 34 *ju jitsu*, 140 *karate*, 22 *kung fu*, 48 *silat*, 76 *taekwondo*, and 47 *wu shu* practitioners. Moreover, Poles practiced the most martial arts. Information regarding gender of the respondents is presented in Table 2.

Table 2. Demographic characteristics of respondents by gender (in %)

	China	Japan	Ukraine	Poland	Malaysia	SouthKorea	Total
Girls	9.1	9.8	2.1	6.4	4.7	5.5	37.6
Boys	12.7	13.8	8.9	10.6	8.1	8.3	62.4
Total	21.8	23.6	11.0	17.0	12.8	13.8	100.0

The respondents consisted of 37.6% girls and 62.4% boys. Among the boys, the majority were Japanese 13.8%, while the fewest were Malaysians 8.1%. Among the girls, Japanese were also dominant 9.8%, while the least represented were Ukrainian 2.1%.

Based on the age data, differences among the surveyed respondents were also observed in relation to this variable (the first age group encompassed the years from the youngest respondent to a teenager while the second age group spanned from teenager to the oldest in the surveyed group). This data is presented in Table 3.

Table 3. Demographic characteristics of respondents by age (in %)

	China	Japan	Ukraine	Poland	Malaysia	SouthKorea	Totals
5-10	3.1	3.2	5.3	2.1	2.1	3.7	17.5
11-16	21.0	11.3	7.2	17.0	12.4	11.6	82.5
Total	24.1	14.5	12.5	19.1	14.5	15.3	100.0

Taking into consideration the designated age ranges (5-10 and 11-16), variations were observed among all surveyed nationalities. Chinese individuals classified into the younger age group numbered 3.1%, while those in the older group were 21.0%. Japanese participants were predominantly represented by individuals in the older group 11.3% compared to the younger group 3.2%. Similar differences were observed among respondents from Poland 17.0% in the older group compared to 2.1% in the younger group, Malaysia 12.4% in the older group compared to 2.1% in the younger group and South Korea 11.6% *vs* 3.7%. Ukrainian groups, on the other hand, were quantitatively similar 7.2% in the 11-16 age group and 5.3% in the 7-10 age group.

Design

The tool used was the Perception of Success Questionnaire (POSQ) in the paper version (in English, Polish and Ukrainian). It is a questionnaire designed to assess respondents' attitudes in relation to variables relevant to functioning in the realm of sports. It consists of twelve affirmative statements presented in the form of responses, along with a scale of potential acceptance or rejection (from A to E, without the response options tabular and a scoring system). The POSQ measurement refers to goal orientation which includes both task and ego orientations and is based on Nicholls' theory. According to this theory, a specific goal orientation is related to one's unique perception of one's own abilities and successes, among other things. Task-oriented people perceive success through the possibility of developing their skills. They judge it by the progression of their skills level. They are characterized by perseverance and striving for perfection during performance of tasks. Ego-oriented people, on the other hand, evaluate success through the possibility of being better than someone else. They are oriented to compare their level of performance with other people and are characterized by the will to be the best [26].

These statements express the following attitudes: 1) "I beat other people", 2) "I am clearly superior", 3) "I am the best", 4) "I work hard", 5) "I show clear personal improvement", 6) "I outperform my opponents", 7) "I reach a goal", 8) "I overcome difficulties", 9) "I reach personal goals", 10) "I win", 11) "I show other people I am the best", and 12) "I perform to the best of my ability" [25].

The research was approved by the Ethics Committee of the Idokan Poland Association, Committee of Scientific Research (Opinion No. A1/2022) and consent was obtained from the heads of the institutions where the tests were performed. All procedures were carried out in full compliance with the Declaration of Helsinki. All participants received detailed information on the aims and methods used throughout the study and gave their written informed consent to participate.

Statistical analysis

The arithmetic mean, standard deviation, coefficient of variation, Spearman's correlation were calculated. Significance was accepted at the level of $\alpha=0.05$. Statistica and LibreOffice Calc were used to analyze data [27].

Results

The first hypothesis concerned the existence of at least a strong correlation between respondents' answers regarding their perception of success and their gender (Table 4).

Table 4. Perception of success and gender of respondents

	Girls			Boys		
	$\bar{x}$	Sd	V	$\bar{x}$	Sd	V
Task orientation	2.33	0.28	12.1%	2.24	0.31	13.8%
Ego orientation	1.69	0.25	14.8%	1.59	0.27	16.9%

$\bar{x}$ – mean, V – variation values, Sd – standard deviation

The data presented in Table 4 indicate a lack of diversity in the responses of children and adolescents involved in CSMA regarding the perception of success (in terms of goal achievement and self-development). On average, girls somewhat agreed (2.33) that success depends on achieving specific goals, while they strongly agreed (1.69) that it depends on ego orientation. Interestingly, boys represented similar approaches (2.24 and 1.59, respectively). The standard deviation values ranged between 0.27 and 0.32.

The coefficient of variation values (expressed in percentages) for ego orientation and task orientation range between 12.1% and 16.9%, indicating low statistical variability of the data. Moreover, the results of the Spearman's rank correlation test yielded a value of r=0.85, suggesting a very strong correlation between gender and perception of success. Hence, the first hypothesis should be accepted.

The second hypothesis pertained to the existence of at least a strong correlation between respondents' answers regarding the perception of success and their age (Table 5).

Table 5. Perception of success and age of respondent

	5-10			11-16		
	$\bar{x}$	Sd	V	$\bar{x}$	Sd	V
Task orientation	2.52	0.54	21.4%	2.16	0.22	10.1%
Ego orientation	1.79	0.50	27.9%	1.62	0.21	12.9%

The mentioned values also indicate variations in responses among respondents categorized by age. Children aged 5-10 on average somewhat agreed (2.52) that success depends on achieving specific goals, while they strongly agreed (1.79) that it also depends on ego orientation. Teenagers (11-16) represented close instead approaches (2.16 and 1.62, respectively). The standard deviation values ranged between 0.21 and 0.54.

The coefficient of variation for ego orientation and task orientation ranged between 12.9% and 27.9%. It should be noted that only in the case of responses from respondents aged 5-10, the variability level was at the average level, while in the remaining cases, it was at a low level. The application of the Spearman's rank correlation test resulted in a coefficient of r=0.86. Therefore, it is also justified to state that a very strong correlation exists between age and the perception of success. Thus, the second hypothesis should be accepted.

The third hypothesis pertains to the least strong correlations between the perception of success by the respondents and their nationality (Table 6).

Table 6. Perception of success and nationality of respondents

	Task orientation			Ego orientation		
	$\bar{x}$	Sd	V	$\bar{x}$	Sd	V
China	2.13	0.31	14.5%	1.53	0.23	15.0%
Japan	2.22	0.31	14.0%	1.64	0.29	17.6%
Malaysia	2.28	0.22	11.2%	2.04	0.29	18.9%
Poland	2.24	0.37	16.5%	1.63	0.38	23.3%
Ukraine	1.95	0.31	15.8%	1.44	0.19	13.2%
South Korea	2.05	0.22	10.7%	1.68	0.13	7.8%

The obtained values shown in Table 6 indicate a lack of diversity in the responses of children and adolescents (categorized by nationality) engaged in combat sports and martial arts regarding the topic of achieving success (in the form of goal and self-development). Children from China tended to agree (2.13) that success depends on achieving specific goals and strongly agreed (1.53) that it depends on ego orientation. Japanese (2.22 and 1.64), Polish (2.24 and 1.63), and Koreans (2.05 and 1.68) represented similar approaches. On the other hand, Malaysians claimed to rather agree with statements related to task (2.28) and orientation (2.04). The situation was different among Ukrainians. Here, opinions about task and ego orientation were moderately associated with the expression "strongly agree". The standard deviation ranged from 0.13 to 0.38.

The calculated coefficients of variation (expressed in percentages) for ego orientation and task orientation ranged from 7.8% to 23.3%. The results of the Spearman's rank correlation test were r=0.65, indicating a strong correlation between perception of success and nationality. Therefore, the third hypothesis should be accepted.

The fourth hypothesis concerns strong correlations between the perception of success by the respondents and the type of martial arts they practice or the activity category they belong to. The martial arts categories included *aikido, goshinjitsu, ju jitsu, karate, kung fu, silat, taekwondo, and wu shu.*. The combat sports category included boxing (Table 7).

Table 7. Perception of success for fighting arts vs. boxing

	Fighting arts			Boxing		
	$\bar{x}$	Sd	V	$\bar{x}$	Sd	V
Task orientation	2.18	0.27	12.3%	2.21	0.32	14.8%
Ego orientation	1.66	0.26	15.6%	1.58	0.28	17.7%

Table number 7 contains values indicating a lack of diversity in the responses of children and adolescents based on the types of practiced martial arts or boxing regarding the perception of success (in terms of goal achievement and self-development). Individuals practicing martial arts somewhat agreed (2.18) that success depends on achieving specific goals, and they strongly agreed (1.66) with ego orientation. The same distribution of results applied to those practicing boxing (2.21 and 1.58). The standard deviation values for this aspect of the study ranged between 0.26 and 0.32.

Coefficient of variation values ranged between 12.3% and 17.7%. Thus, there was low statistical variability in the data. The calculations for the Spearman's rank correlation test yielded a result of $r=0.87$. This indicates that in this case as well, there is a very strong relationship between perception of success and practicing martial arts or boxing. Therefore, the fourth hypothesis should be accepted.

Discussion

The POSQ is popular tool which is used in research connected with young people who practice and play sports [28, 29]. It was gradually developed by its creators over ten years. As a result, this research tool was refined to a twelve-point scale (both for adults and children) [30].

The results of the current study are generally compatible with similar research on the effects of exercise on young people engaging in CSMA practice [31-33]. However, the early stages of some studies raise questions about any physical activity among children and adolescents [34]. In addition, goal pursuit is related, among other things, in the case of girls and boys to their choice between antisocial and prosocial behaviors. Investigating the active factors in this process is essential for determining the role of moral behaviors in sports, which can be linked to ego orientation and task orientation. This is because different factors can play important roles in that choosing [35]. For example, in a study conducted by Tomczak et al., a statistically significant effect of gender on ego orientation was observed. The studied men were characterized by higher scores in the ego factor than women (men: $M = 3.87$, $SD = 0.88$; women: $M = 3.48$, $SD = 0.97$). Moreover, it was observed that highly accomplished athletes were characterized by higher scores in the ego subscale than recreational athletes (high accomplished athletes: $M = 3.97$, $SD = 0.86$; recreational athletes: $M = 3.40$, $SD = 0.94$) [27].

Another study also confirmed that "the results of the Spearman rank correlation yielded a statistic of 0.35, indicating a weak correlation between the type of cultivated fighting style and the perceptions of success on the part of participants. Moreover, because the calculated ratio, 2.83, is higher than 0.05, the hypothesis that there is no statistically significant dependence of the perception of success in the martial arts upon the type of cultivated martial art or combat sport being practicing must be accepted" [2].

An important element of such research would be the direct relationship between individuals practicing and the accompanying martial arts. "Martial arts practitioners frequently cite their training as being responsible for key areas of self-improvement including the mental and emotional realms. Can martial arts training actually induce a change in personality within the practitioner? In sport psychology, this notion, referred to as the change hypothesis, is in contrast to the gravitation hypothesis, which states certain personalities are attracted to the martial arts and are more conducive to succeeding at the martial arts. A literature review of existing research was merited to determine which hypothesis is valid. Yet, there are a few benchmark studies that seem to offer more concrete insights, and the martial arts community should take note of them. These studies not only suggest that the martial arts can indeed have positive effects on personality, but also imply the outcome is contingent upon proper teaching which includes traditional martial arts values and philosophy" [36].

Limitations of the Study

The limitations of this study include the omission of cultural aspects and the extension of the study sample to include individuals representing other martial arts. The aforementioned limitations include differences in the selection of individuals, age, and nationality.

Future research should encompass both the expansion of hypotheses and the examination of young respondents within a broader cultural context. Methodologically, it would also be appropriate to incorporate the POSQ test as one of several research instruments in future analyses. As mentioned above, "the fact that differences in these mediating factors can be identified indicates that in future research these and possible other mediating factors should be considered when trying to determine social-psychological outcomes of Martial Arts and Combat Sports" [37].

Conclusions

The findings from the study indicate a similarity in the attitudes of young respondents from the CSMA practitioners in the six countries (Poland, Ukraine, China, Japan, Malaysia, and South Korea). It can therefore be hypothesized that since country of residence has no influence on attitudes and opinions regarding task orientation and ego orientation, conducting an analysis using POSQ may be culturally universal in the CSMA environment.

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EFFECTIVENESS OF VIRTUAL ENVIRONMENT EXERCISES ON PHYSICAL PERFORMANCE

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
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Abstract:

Background: Virtual environment exercises are becoming more and more popular. Virtual environment activities, which are used for different purposes in many areas, are quite new in the field of sports and need study findings. The purpose of this study was to investigate the effects of 8 weeks of virtual reality (VR) and field-based fitness exercises on the performance characteristics of young individuals.

Methods: Thirty participants, with an average age of 19.7 ± 1.3 years and who had not previously engaged in fitness exercises, volunteered for the study. The participants were randomly assigned to either a fitness exercise group or a virtual exercise group. Measurements of height, weight, static balance, flexibility, sit-up, plank performance, standing long jump, and leg strength were taken before and after the intervention. The data were analyzed via analysis software.

Results: The findings of the study revealed that all the values of the measured performance characteristics changed significantly in comparison with those in the preintervention phase. A comparison of these variables revealed that, in comparison with the VR group, participants exposed to fitness training improved their flexibility, long jump, BMI and leg press. On the other hand, the VR group demonstrated significantly greater improvement in balance performance than did the fitness group.

Conclusions: Based on these findings, VR-based exercise interventions may be more effective than traditional fitness training in improving balance, whereas traditional fitness training appears superior for leg strength, flexibility, and long jump performance.

Introduction

The evolution of modern lifestyles has sparked growing demand for innovative exercise formats that integrate advanced technologies. Training now often employs velocity-based and specialized loading techniques to enhance performance and reduce injury risk—especially important for digitally immersed younger populations [1]. Virtual reality (VR) applications—such as HoloLens-based body tracking systems for musculoskeletal training—provide engaging, cost-effective environments that enhance balance and coordination while eliminating hazards associated with real-world exercises [2]. Extended reality (XR) frameworks are increasingly adopted in education settings—particularly in medical, architectural, and tourism training—because they offer immersive learning opportunities when physical resources or real-world environments are inaccessible or costly [3,4].

Virtual environments or virtual reality refer to software that involves an interface presenting a 3D computer-simulated environment. This is accomplished by including computer graphic systems as well as different display and interface equipment [5,6]. Over the years, virtual training has been effective in improving athletic performance.

Computer-assisted training refers to a training system in which trainees are instructed through computer-generated images in relation to sports. By enabling individuals to recreate movements they execute during training, this method can enhance athletes' strength performance. However, another benefit of virtual training is that athletes become familiar with their results within a short time. This information is valuable for those who perform different exercises and need to shift their training or calorie-taking plans. Furthermore, literature reported that the strength performance of athletes who were trained through virtual training aids was greater than that of the machine control group [7]. The researchers opined that these alterations may have arisen as a result of the feedback athletes attained in the virtual environment in the course of coaching to make adjustments instantly during a practice session. Furthermore, virtual training could help athletes hone in on some aspects of their strength training that might otherwise be problematic for them. For example, synthesized research with the aim of determining the impact of a new virtual training model. Research has shown that while exercising with the aid of new virtual exercise equipment created to target certain muscle areas, athletes are able to exhibit greater strength than they would if they exercised without virtual assistance [8]. This means that virtual training is a good training approach for athletes who want to improve their general strength performance. One of the significant advantages of virtual training is the ability to design individual training programs relevant to abilities. A study revealed that when athletes used a special training-through strategy that highlighted virtual training programs of their capacities and deficits, their strength performance was greater than that of standard training procedures [7]. The insight was attained through the tactic of training in specific parts of the athletics to support independent growth of the rest where extra force is perceived.

However, some challenges that have been reported in the literature include the limitations of virtual training in terms of strength performance. For example, a study revealed that coaches who exclusively utilized virtual training equipment that they had presumably never mastered in a real-life setting showed poor strength performance [9]. This means that virtual training should walk side by side with traditional training for the benefit of the latter to be felt. Virtual training may influence strength performance in such a way that support can be offered when needed, weaknesses can be addressed, and training methods can be adjusted to individual cases. Nevertheless, the general point should be noted that such training should be used in conjunction with more conventional forms of training to achieve maximal results. Hence, the comparison of real exercises with virtual exercises becomes important. Another factor is whether exercise in a virtual environment has different effects on different components of sports performance, such as strength skills, than real exercise does. In response to this fundamental research question, this study analyses the impacts of two contrasting training conditions on strength, explosive power and flexibility.

Material and Methods

Participants

This study is an experimental research designed in a randomized controlled pretest-posttest design. A total of 30 healthy individuals (male) with an average age of 19.7 ± 1.3 years volunteered to participate in the study. Individuals who had not previously performed regular fitness exercise and had not exercised while wearing VR glasses had to meet the inclusion criteria for the study. The study group was formed by drawing lots from the invitation announcement made to students who are actively studying at the university.

Procedure

Participants were randomly assigned to one of two groups: the fitness group (n=15) or the virtual exercise group (n=15). The fitness group performed calisthenic exercises for 30 minutes, twice a week, whereas the virtual exercise group engaged in exercises within a virtual environment for 30 minutes, utilizing movement patterns similar to those in the fitness regimen. Both exercise programs were implemented for 8 weeks and 2 days a week. The demographic and performance characteristics of the participants were assessed via standardized tests before and after the intervention. The fitness exercises performed by the participants for 8 weeks and their content are shown in Table 1.

Virtual exercise application

The virtual exercises were conducted via the Oculus Quest II VR set and the FitXR - Box, HIIT, Dance, Sculpt, Combat application. The application includes movements such as punching, kicking, lateral jumping, squatting and standing, jumping, and turning, all of which are performed on music at varying intensities and durations. Each participant completed a 15-minute moderate-intensity exercise session with two sets (130–150 bpm) to conclude a daily session. 5 virtual reality glasses were used in the study. Therefore, virtual reality exercises were performed in 3 groups of 5 participants.

Table 1. Applied fitness program

Movements	Load	Rest	Set	Rest between sets
Warm up (jumping jacks)	1 min	30 sec.	3	30 sec.
Knee pull up				
Jump with arms and legs out to the side				
Squat	30 sec.			
Plank		1 min.	3	2 min.
Knee pull in push-up				
Squat jump				
Half Curl up				

Data collection techniques

Before and after the study, the participants completed the following tests, from which the study data were collected:

- *Height and weight measurements*: Height (in cm) and weight (in kg) were recorded via a meter and scale.
- *BMI Calculation*: Body mass index (BMI) was calculated via the World Health Organization formula (kg/m^2).
- *Flexibility measurement*: Flexibility was assessed via the sit-and-reach test. After a 5-minute active warm-up, the best performance out of two trials was recorded in centimeters on a flexibility bench.
- *Plank measurement*: The maximum duration the participants could hold the plank position was recorded in minutes.
- *Sit-up measurement*: The number of correctly performed sit-ups in 30 seconds was recorded.
- *Balance measurement*: The Flamingo balance test was used, with the number of balance errors (loss of balance) during a 30-second single-leg stance on a balance board recorded as errors.
- *Standing long Jump*: After a 5-minute active warm-up, the participants jumped from a standing position without taking a step, and the best distance achieved from two attempts was recorded in centimeters.
- *Leg strength*: The 1RM (one-repetition maximum) leg press test was used. A standard leg press machine in a gym was employed for the test. The participants performed a 5–10 minute light cardiometabolic warm-up followed by dynamic stretching to prepare the muscles and reduce the risk of injury. A warm-up set of 8–10 repetitions at approximately 50% of their perceived maximum weight was performed. After a short rest (1–2 minutes), a set of 3–5 repetitions was performed at approximately 70% of their perceived maximum. After each warm-up set, the weight progressively increased, with participants performing 1-2 repetitions at each increase. Typically, increments of 10-20 kg was added until the participant could no longer complete a full repetition. The rest of the intervals between attempts lasted 2–4 minutes. The maximum weight the participant could complete a full leg press repetition with the proper form was recorded as the 1RM. The maximum weight was generally determined within five attempts. The researcher assisted throughout the exercise to ensure proper form.

Statistical analysis

The data obtained from the study were analyzed via SPSS software. The demographic data are presented as the means and standard deviations. After conducting a normality test, (Shapiro-Wilk: $p>0.05$) it was determined that the data followed a normal distribution. The homogeneity of the study groups and the absence of significant differences in their pretest measurements were confirmed via the independent samples t test. To assess the changes in the observed variables between the pre- and posttests, the paired samples t test was employed. The comparison of pre- and post-test performance between the study groups was also conducted via the independent samples t test. The results were considered statistically significant at the $p<0.05$ level.

Results

Before starting the study, the study groups had to have similar characteristics. The results of the analyses made for this are shown in Table 2.

The pretest results of the individuals who participated in the study, categorized by their respective groups, are shown in Table 2. An examination of the table reveals that the participants share similar demographic characteristics. The sports performance characteristics are presented in Table 4. In line with the aim of forming a homogeneous group, it was determined that the observed characteristics of both groups did not differ statistically.

Table 2. Demographic and performance characteristics of the participants

	Fitness (n=15)	VR (n=15)	t	p
Age (year)	19.8±1.4	19.6±1.2	-0.269	0.790
Body height (cm)	169.6±3.9	172.8±5.6	1.571	0.127
Body weight (kg)	69.8±5.5	68.8±7.1	-0.029	0.977
BMI (kg/m²)	24.2±2.3	23.4±1.9	-1.110	0.276

Note: ± – Standard Deviation, t – Student's t-test, p – p value

In order to test the efficiency of the study, the results of the test to analyse the level of influence of the observed variables are shown in Table 3.

Table 3. Pre- and post-measurement results of performance elements (mean ± SD)

	Pretest	Posttest	F	p
Balance (fails)	4.3±2.1	1.6±1.5	91.57	0.001
Flexibility (cm)	6.9±6.1	13.1±8.8	70.868	0.001
Curl up (repetitions)	23.3±2.8	30.3±4.7	1656.281	0.001
Plank (min.)	2.7±1.3	3.6±1.4	164.550	0.001
Long jump (cm)	208.8±17.6	240.2±25.4	3708.124	0.001
BMI (kg/m²)	23.3±2.1	24.7±2.5	6.644	0.015
Leg press (kg)	125.6±20.5	156.6±23.6	1299.774	0.001

Note: F – Repeated measures of Anova score, p – p value

The pre- and post-measurement scores of the participants' performance characteristics are shown in Table 3. When the table was examined, all the performance characteristics significantly changed compared with the initial scores after the 8-week exercises.

The results of the test performed to compare the effects of the exercise types applied in the study are shown in Table 4.

Table 4. Comparison of performance elements according to study groups

	Fitness Group (n:15)			VR Group (n:15)		
	Pretest	Posttest	Differences	Pretest	Posttest	Differences
Balance (fails)	4.4±2.3	2.2±1.7*	-2.2±2.1	4.2±1.8	1.1±1.1*	**-3.1±1.3**£
Flexibility (cm)	8.2±6.4	17.4±9.6*	**9.2±10.6**£	5.6±5.8	8.6±5.3*	3±1.6
Curl up (repetitions)	23.2±2.6	31.1±2.8*	7.9±1.6	23.4±3.1	29.4±6.1*	6.1±4.1
Plank (min.)	2.94±1.2	3.8±1.4*	0.8±0.2	2.64±1.3	3.43±1.4*	0.7±0.4
Long jump (cm)	211.4±16.9	249.2±17.2*	**37.8±10.2**£	206.2±18.5	231.3±29.5*	25.1±20.1
BMI (kg/m²)	24.2±2.3	26.4±1.8*	**2.2±2.1**£	23.4±1.9	23.1±2.1	-0.3±0.5
Leg press (kg)	128.1±23.8	166.3±23.6*	**38.2±7.9**£	123.2±17.1	147.1±19.8*	23.9±8.1

* Significant difference within group at p<0.05 level, £ significant difference between group at p<0.05 level

The results of the difference analysis – independent samples t test – between the pretest and posttest performance scores of the participants, on the basis of their study groups, are presented in Table 4 and Figure 1. A review of the data in the table revealed that the pretest results did not significantly differ between the study groups. There were significant changes in the variables observed compared with the first measurements in both study groups, except for the BMI values of the VR group. When the observed variables between the study groups were compared, the fitness group presented significant improvements in flexibility, long jump, BMI and leg press performance measures compared with the virtual group. In contrast, the VR group showed a statistically greater change in balance performance than the fitness group did. There was no significant difference in plank or curl-up performance between the groups compared with the baseline.

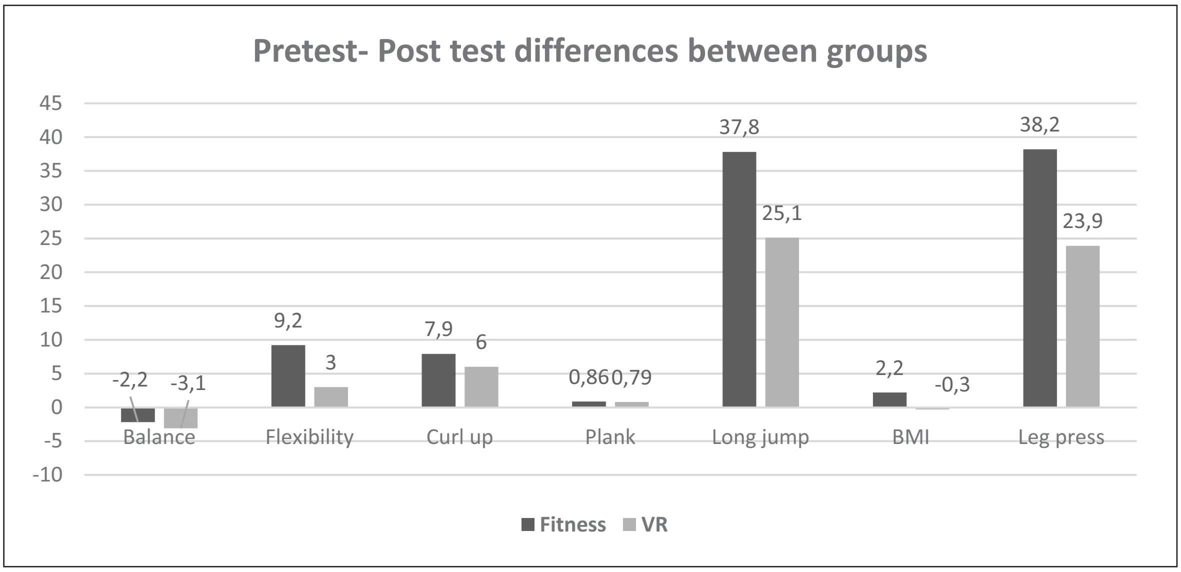

Figure 1. Pretest–posttest changes in the groups (means)

Discussion

In this study, we investigated the effects of non-equipment strength training and strength training in a virtual environment on the athletic performance characteristics of adult individuals. To achieve this goal, we tested the participants' leg strength, explosive strength, balance, flexibility, and abdominal strength. At the conclusion of the study, all observed variables, except for body mass index (BMI), showed significant changes compared with the baseline measurements for both groups.

Conventional fitness training consists of strength training, endurance training, flexibility exercises, and sport-specific programs. As shown in this paper, previous studies suggest that traditional fitness training develops every fundamental aspect of physical fitness and the physical aspect of sports performance. For example, a meta-synthesis of various studies investigated the effects of strength training on physical fitness and performance with the goal of enhancing rowing in female sports. Research has revealed modest positive effects on the maximal strength of the lower limbs and sport performance, indicating that traditional strength training enhances some athletes' physical fitness components [10]. Additionally, periodized resistance training (PRT) has increased army physical and skills performance, which indicates that structured periods of resistance sports training are beneficial for both overall and skill-associated fitness [11]. CrossFit, also known as the HIFT for high-intensity functional training, has also been shown to enhance general and sport specifications among athletes. Research on samples of kickboxers has revealed gains in the abdominal muscles, pull-up, handgrip force, and other physical and sports performance dimensions. CrossFit was found to be effective in improving traditional training techniques [12]. Moreover, meta-synthesis on HIFT affirmed that this training augments muscle strength, power, flexibility, and athletic performance, which is pertinent to skills and events' training and actualization, although it does not notably advance endurance and agility [13]. Among the best-known categories of fitness exercises are strength training and aerobic exercises, both of which have been determined to help facilitate help in building muscles. According to a comparative study established that conventional resistance exercise regimens lead to significant improvements in muscle strength across various age groups [8].

Other exercises that have also improved balance include traditional fitness exercises, balance training, and other functional exercises. A meta-analysis conducted by researchers revealed that traditional balance training significantly increased balance performance in older adults, thereby reducing the risk of falls. Consistent with the literature, the leg strength, abdominal strength, flexibility, and balance performance of athletes engaging in traditional fitness exercises significantly improved by the end of this study [14]. VR training has been identified as a novel method for enhancing physical fitness and sports performance. The primary advantage of exercising in virtual reality is that it allows individuals to engage with programs in virtual environments that cannot be replicated in reality. Another study revealed that VR training positively influences muscular fitness, cardiorespiratory fitness, balance, and agility, contributing to the physical quality of life among individuals with intellectual disabilities. Consequently, the authors recommend VR-based exercise for further systematic review [15]. This suggests that, when properly developed, VR training can be particularly useful in enhancing physical fitness components for specific populations with special needs. Additionally, research comparing the benefits of VR exercise on the functional fitness of older adults has revealed meaningful positive changes in upper and lower body flexibility, upper body strength, cardiorespiratory endurance, balance, and agility. These improvements were noted up to 12 weeks after the intervention was completed [16]. Both VR and exergaming have been said to help build muscles, as are other virtual exercises. A systematic review revealed that VR enhances the advantages of physical capacity, which involves muscle strength plus extremity operation in both stationary and KVM exercise training and is effective for individuals with typical and chronic disease [17]. Additionally, in relation to the benefits of virtual exercise on balance, showed that balance training with Nintendo Wii had a positive effect on balance function in women with osteoporosis more than home exercises, which could be provided by another study [18]. Researchers have also noted that VR exercise can decrease the risk of falls, which is a major issue in osteoporotic patients. Thus, the current VR training for osteoporotic patients could be used to both boost and prolong functional fitness. In the analysis of these two training modalities, it can be assumed that the two provide many benefits.

The current traditional fitness training modality has been widely reported to improve almost all the elements of fitness and sporting performance in almost all the client bases of athletes. It is a formal approach to training and comprises a proper structure and effective method that enhances the quality of the training in enhancing performance in sporting activities [19,20]. On the other hand, virtual reality (VR) training has numerous advantages, such as immersion in the environment and real-time feedback, most importantly for restoring internal balance and increasing the agility of athletes. Since VR training is cost-effective, easy to organize and may involve participants who need different teaching methods because of their age or disability [15,16], it is easily acceptable. Nonetheless, VR-based physical fitness training may not be as effective as normal fitness training in developing important components of fitness, such as maximal strength and endurance, which are vital in many sports, as identified by researcher [12]. Moreover, more specific effects of VR training in relation to lasting improvements in sport-specific performance have not been investigated and elaborated as widely as conventional approaches.

Stuart et al. revealed that virtual reality (VR) exercises outcompete traditional exercises toward enhanced balance and strength in all individuals. Published studies have shown that VR training is effective in chronic ankle pathologies, as it leads to an improvement in patients' static and dynamic balance [21] and, in pathological aging, hip extensor and hip muscle strength and balance control in older adults [22]. Nonetheless, several works indicate that VR and conventional training result in similar significant enhancements in balance and reduce fall risk among nursing home residents [23]. Second, combined theoretical VR and practical balance exercise interventions have revealed greater effects on the lower limb muscle strength and balance and functional movement of elderly men, in addition to VR training and conventional balance training [24]. These results indicate that VR exercise is effective, but combining both might lead to the best result concerning the reduction in the risk of falling and the overall physical functioning of older people.

Studies have shown that traditional exercise routines and VR training can augment multiple components of physical fitness with varying improvements when conventional fitness training is considered. The results show that conventional training yields a much greater improvement in flexibility and explosive power, whereas VR-based training results in a greater increase in the balance of the variables considered. This type of VR is aligned with the current literature to find its application in balance training for fall prevention and improvement in functional fitness in older adults and per populace with neurological issues [10,11,25]. Recent research has provided valuable insights into lower limb biomechanics across different athletic populations. A comparative study of folk and ballroom dancers revealed significant differences in dynamic balance and lower limb kinematics, with ballroom dancers demonstrating superior postural control during rotational movements, likely due to their specialized training in maintaining upright postures during partnered dances. Soccer officials were also examined, showing that referees exhibit greater explosive power in vertical jumps compared to assistant referees, though both groups displayed similar dynamic stability during change-of-direction tasks - suggesting position-specific physical demands influence lower limb conditioning. Further investigations into the relationship between isokinetic strength and jumping performance found knee flexion torque to be strongly correlated with squat jump height, highlighting the importance of hamstring strength in explosive lower-body movements. Interestingly, the dance comparison study additionally noted that folk dancers generated greater ground reaction forces during landing sequences, possibly reflecting the more percussive nature of traditional dance styles versus the fluid motions of ballroom. Collectively, these studies emphasize how sport-specific movement patterns lead to distinct neuromuscular adaptations in the lower extremities, with implications for both performance enhancement and injury prevention strategies tailored to each athletic discipline's unique biomechanical demands The findings underscore the need for targeted training programs that address the particular strength, power, and stability requirements of different sports and dance forms to optimize performance outcomes [26-29].

Limitations of the study

This study has some limitations that should be considered. First, the 8-week intervention period may have been short to fully assess long-term adaptations to virtual environment exercises. Second, the study evaluated only a select set of performance metrics (balance, flexibility, strength, etc.), potentially overlooking other key fitness indicators such as cardiovascular endurance or agility. Future research with longer durations and a broader range of assessments could provide deeper insights.

Conclusions

In conclusion, conventional fitness training and virtual training have relative advantages in terms of sports performance. Traditional fitness training can still be employed beneficially because of its effectiveness in increasing muscular strength and cardiovascular endurance and decreasing the risk of injuries. On the other hand, virtual training is more effective for balance improvement due to its interactive and immersive nature, which is important since it helps enhance stability and coordination and enhances cognitive growth among athletes. As virtual training is relatively new, it can supplement or, in some cases, replace conventional approaches to training. Future studies should compare the differences in efficacy between these two modalities over more extended periods and examine the possible combined effects on athletic performance. From the observations above, it is evident that combining conventional and virtual reality training could provide a more holistic approach to physical fitness training with reference to the strengths posited in the study. Future research should therefore focus on these training synergy effects by performing studies on the application of these training methods for increasing physical fitness in different target populations.

Practical implications

Virtual reality (VR)-based exercises can be an effective alternative to traditional fitness training, particularly for improving balance in young individuals. While traditional fitness training is more beneficial for enhancing flexibility, leg strength, and jumping performance, VR exercises may be useful for individuals who prioritize balance development. Coaches, trainers, and rehabilitation specialists can incorporate VR-based activities into training programs, especially for populations needing balance improvements, such as beginners or individuals recovering from injuries.

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Informed consent statement: Informed consent was obtained from all subjects involved in the study

Data availability statement: The data presented in this study are available on request from the corresponding author**.**

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THE EFFECT OF THE FIFA 11+ WARM-UP PROGRAM AND DYNAMIC WARM-UP ON SPEED AND AGILITY OF FEMALE FOOTBALL ATHLETES IN VIEW OF MUSCLE ENDURANCE: A FACTORIAL DESIGN

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Background: This study aimed to (1) analyze the differences in the effect of the FIFA 11+ program and dynamic warm-up on speed and agility in female soccer athletes; (2) analyze the differences in the effect of high and low muscle endurance on speed and agility in female soccer athletes; (3) analyze the interaction between the provision of the FIFA 11+ program and dynamic warm-up on speed and agility in female soccer athletes in terms of muscle endurance.

Methods: This research uses an experimental approach with a 2x2 factorial design. The data analysis technique for hypothesis testing uses a two-way ANOVA test.

Results: The research findings showed that (1) there was a difference in the effect of the FIFA 11+ warm-up program and dynamic warm-up on speed, with a significance of 0.001 and agility with a significance of 0.000 in female soccer athletes; (2) there was no difference in the effect of high and low muscle endurance on speed, with a significance of 0.118 and agility with a significance of 0.158 in female soccer athletes (3). There was no interaction between giving the FIFA 11+ program and dynamic warm-up on speed and a significance of 0.383 and agility with a significance of 0.120 in female soccer athletes.

Conclusions: It was concluded that the FIFA 11+ warm-up method had an effect on increasing speed and agility compared to the dynamic warm-up in female soccer players. However, the FIFA 11+ warm-up method can be effectively applied when entering the preparation period in the periodization of the training program.

Introduction

Interest and motivation are key factors influencing women's participation in football [1]. However, despite increasing enthusiasm and motivation, amateur female football players who are heading towards professionalism are not able to show good performance and prime condition on the field. Football prioritizes physical aspects such as speed, agility, strength, and excellence. These physical components can be associated with the performance of female football athletes during the match [2]. Data from the results of physical condition tests show that the overall physical condition level of female football athletes remains in the sufficient category [3]. Furthermore, the data shows that 50% of the speed levels of female players are still in the moderate category [4]. This shows that the level of players' physical components, such as speed and agility, is still insufficient. With the growing interest of women in football in Indonesia, it is increasingly certain that a good level of physical conditioning is essential. Therefore, good physical fitness may also have an impact not only on reducing the risk of injury but, most importantly, on performance on the field.

In addition to preventing muscle injuries, warm-up is considered an important factor that helps improve performance in athletes [5,6]. F-MARC developed FIFA 11+ consists of three parts with 27 exercises [7,8], which must be performed in a specific order at the beginning of each training session. FIFA 11+ has been shown to be effective in reducing the rate of lower extremity injuries (especially the knee), at least in teams that practised this warm-up twice a week for more than three consecutive months. For any warm-up program to be successful, it must be an effective way to prepare soccer players. It must also be fun and practical for players and coaches. FIFA 11+ is an efficient method to achieve optimal physiological readiness [9-11].

In previous studies, it was found that the FIFA 11+ warm-up can increase speed in young amateur soccer players [12]. Meanwhile, warm-up exercises performed for about 10 weeks, 2 times a week, yielded an increase in physical fitness, especially leg muscle agility [13]. FIFA 11+ Warm-up is an exercise program that can increase stimulation of the nervous system to increase the reactive capacity of the neuromuscular system. Exercises that focus on core stability, eccentric muscle, proprioception, and dynamic stabilization can induce myotatic stretch reflexes to produce a stronger response from the muscles during running [14]. Additional studies have reported that the FIFA 11+ Program can improve lower limb balance, core stability, knee strength [15-17], and running and jumping ability in soccer players [18,19].

Thus, this study aims to (1) analyze the differences in the effects of the FIFA 11+ program and dynamic warm-up on speed and agility in female soccer athletes; (2) analyze the differences in the effects of high and low muscle endurance on speed and agility in female soccer athletes; (3) analyze the interaction between the provision of the FIFA 11+ program and dynamic warm-up on speed and agility in female soccer athletes in terms of muscle endurance.

Material and Methods

Study design

This study employed an experimental design to examine the effects of a treatment that was deliberately given by the researcher (Table 1). This experimental study used a 2x2 factorial design [20]. The sample in this study was all young female soccer athletes with a total of 24 people (aged 19.4 ± 0.7 years). Two study groups received different treatments, namely the provision of the FIFA 11+ method and a dynamic warm-up. To meet the requirements of a factorial design, this study uses a moderator variable of muscle endurance to determine high- and low-endurance groups.

Table 1. Study design

2x2 Factorial Design		Muscle Endurance (B)	
		High (B1)	**Low (B2)**
Warm UP program (A)	**FIFA 11+ (A1)**	A1B1	A1B2
	Dynamic Warm-Up (A2)	A2B1	A2B2

Note: **(A1B1)** FIFA 11+ group with high muscle endurance, **(A1B2)** FIFA 11+ group with low muscle endurance, **(A2B1)** Dynamic warm-up group with high muscle endurance, **(A2B2)** Dynamic warm-up group with high muscle endurance.

Procedure

The program was implemented for the research sample across 18 sessions delivered 3 times a week to determine the effects of the treatment given. The program was designed according to the group division that had been used to obtain the results of the initial test. After the program was administered, participants continued the same main training sessions until cool down with no differences between the two treatment groups. The two intervention group programs are presented in Table 2.

Table 2. Experimental Program

Warm Up Exercise	Exercise Component	Set	Duration
A. FIFA 11+	Part 1: Running Exercise straight ahead, hop out, hop in, circling partner, shoulder contact, quick forward, backward	2	8 min
	Part 2: Strength, Plyometric, and Balance Exercise The bench: one leg lift and hold Side Bench: with leg lift Hamstring: Nordic exercise Single-leg: test your partners Squat: one leg squats Jumping: box jump	 3 3 1 2 2 2	10 min
	Part 3: Running Exercise across the pitch, bounding, plant and cut	2	2 min
B. Dynamic warm-up	Part 1: Jogging	1	3 min
	Part 2: Dynamic Exercise (shuffle right/left, carioca right/left, forward and backward skip, lateral skip, open and close gate, forward lunge, side lunge, broad jump, skater hops.	3	15 min
	Part 3: Sprint Exercise forward sprint, shuffle to sprint, tuck jump to sprint, single leg hops to sprint, half kneeling to sprint.	2	2 min

Data collection

The data collection instrument to assess speed included the 30-meter Sprint Test with a validity of 0.920 and reliability of 0.920. Agility was measured using the Illinois Agility Test with a validity of 0.560 and reliability of 0.96. Participants performed three separate 30 m sprint tests at 4 min intervals [21]. The times were recorded using a CASIO HS-70W1JH stopwatch, and the fastest time was used as the final result. The Illinois Agility Test involves a prone starting position, a quick transition to a standing position, and then running over a multidirectional obstacle course at maximum speed [22]. The test course is 10 meters long and 5 meters wide, with cones used to mark the start, finish, and turning points. The test is performed twice, and the fastest time is recorded as the final result.

Statistical analysis

Data normality was tested using the Shapiro-Wilk test by checking the frequency distribution of samples based on the normal distribution of single data or single-frequency data. The results were presented as mean ± standard deviation (±s). Hypothesis testing was performed using the two-way ANOVA test. If there was an interaction, the testing was continued with the Tukey test. Statistical significance was set at $p<0.05$. Data analysis were performed using the IBM SPSS Version 26 program.

Results

The Shapiro–Wilk normality test before entering the hypothesis test showed that all experimental group data were normal at $p> 0.05$. After being an intervention performed for 8 weeks, there was a difference between the two

Table 3. Changes after intervention

Intervention	Dependent Variable	Pre	Post	Significance	Effect Size
FIFA 11+	30 m sprint test	5.3 ± 0.3	4.9 ± 0.2	0.004*	0.6
	Illinois Agility	18.9 ± 0.8	17.7 ± 0.6	0.000*	0.6
Dynamic Warm-Up	30 m sprint test	5.34 ± 0.2	5.37 ± 0.3	0.339	-
	Illinois Agility	19.42 ± 0.9	19.4 ± 0.9	0.674	-

Note: Significant differences before and after intervention within groups: * $p< 0.05$
Values are presented as mean ± standard deviation (SD)

interventions in the effect on speed and agility in amateur female soccer athletes. The FIFA 11+ program has a significant effect on sprint and agility running performance ($p < 0.05$). In the dynamic warm-up program, there were no changes after the intervention, as shown in Table 3.

To examine the factorial effects in this study, the next step was to test the results based on the research factors. Since all data were normally distributed, the analysis was continued with parametric statistical analysis, with the results (two-way ANOVA test) presented in Table 4.

Table 4. Two-way ANOVA test of intervention results

Source Based	Variable	F	Significance
Warm-Up Program	Speed	14.923	0.001*
	Agility	21.101	0.000*
Muscle Endurance	Speed	2.671	0.118
	Agility	0.060	0.158
Interaction	Speed	0.795	0.383
	Agility	0.011	0.120

Note: Significant difference before and after the intervention in the groups reviewed by factorial: * $p< 0.05$
F – value of ANOVA test statistic

The results of the two-way ANOVA (Table 4) show a significance value of 0.001 for speed, while the significance value for agility was 0.000. There was a significant difference between the FIFA 11+ warm-up program and the dynamic warm-up in the effects on speed and agility in female soccer athletes. The significance values were 0.118 for speed and 0.158 for agility. It can be explained that there was no significant difference in the effects of high and low muscle endurance on speed and agility in female soccer athletes. The significance was 0.383 for speed and 0.120 for agility. There was no interaction between the effects of the FIFA 11+ warm-up program and dynamic warm-up on speed and agility in female soccer athletes.

Discussion

This study highlights two warm-up programs that can provide benefits to both sprint and agility performance. However, our findings indicate that regular dynamic warm-ups do not improve running performance, perhaps only providing a readiness effect on the muscles for that performance. FIFA 11+ Warm-up is an exercise program that can increase the stimulation of the nervous system to improve the reactive capacity of the neuromuscular system [23]. The program focuses on core stability, eccentric muscles, proprioception, and dynamic stabilization [24], and can induce myotatic stretch reflexes to produce stronger muscle responses during running [25-30]. All FIFA 11+ Warm-up movement models involve repeated lengthening-shortening cycles that produce kinetic energy; thus, the neuromuscular system must react quickly to produce concentric contractions that optimize muscle performance during running [31]. In addition, repeated stretch-shortening cycles reinforce specific movements biomechanically, while muscles, tendons, and ligaments are strengthened functionally [32].

These findings are consistent with Trajković [33], who reported a similar increase in agility compared to the standard dynamic warm-up. The plausible explanation is that the FIFA 11+ program includes sprinting, agility, and plyometric training in addition to neuromuscular training [34]. The improvements may be partially attributed to increased muscle temperature [35]. The lack of influence from high and low muscle endurance suggests that other physical factors may contribute to the speed and agility of female soccer players. Speed is the most basic component of athletic performance across sports, including soccer, and can be influenced by factors such as the athlete's leg length and leg explosive power [36]. Thus, it is likely that other physical component factors can affect the speed of female soccer athletes. The results of this study are supported by similar findings in adult soccer players and adolescent futsal players [37,38].

The results of the analysis showed that muscle endurance did not have a significant effect on the agility of female soccer players. In soccer, agility plays a critical role in physical mobility. Agility enables athletes to evade opponents, move effectively without the ball, and control dribbling. However, agility is not a single physical component, but is composed of coordination, strength, flexibility, reaction time, and power components [39]. Therefore, speed and agility in female soccer athletes may be influenced by factors other than muscle endurance. These results indicate that the emphasis in the warm-up program on intensity and frequency relative to athletes' muscle endurance does not significantly affect speed and agility. The warm-up program is specifically aimed at preparing the athlete's body for training. This readiness to train is marked by an increase in body temperature and heart rate as a physiological response that indicates readiness to perform subsequent exercises at higher training intensities [40].

However, this study also found that the FIFA 11+ warm-up program had a moderately significant effect on the speed and agility of players. This indicates that the FIFA 11 + Warm-up program may contribute to increasing the speed and agility of female soccer players when integrated alongside structured physical training. These findings align with previous research showing improvements in agility components after the intervention [33]. Another study also found that implementing the FIFA 11+ program before main training has a positive effect on players' running ability, especially on increasing speed and agility [14].

Study limitations

This study was subject to several limitations. First, during the intervention, not all athletes were located in the same training centre in Batu City. Therefore, there was no control of their activities and dietary intake, which may have resulted in athletes not being in prime condition. Second, during the treatment, some athletes had to follow the tournament agenda at their respective schools and campuses, which disrupted the research intervention. Third, the study coincided with the month of Ramadan, leading to changes in the training program and schedule compared to normal conditions. These limitations suggest that future research should involve larger samples. The study period should also be considered so that it is not hampered by the fasting time of Ramadan, which is also a limitation of this research.

Conclusions

Based on the results of the previous studies and discussion, it can be concluded that there is a difference in the effect of the FIFA 11+ warm-up program and dynamic warm-up on speed and agility in female soccer athletes. There is no difference in the effect of high and low muscle endurance on speed and agility in female soccer athletes. There was no interaction between the provision of the FIFA 11+ program and dynamic warm-up on speed and agility in female soccer athletes. These findings suggest that coaches and athletic trainers should consider the FIFA 11+ warm-up program during the preparation for the competitive season.

Practical implication

The FIFA 11+ program can be effectively implemented before the main training session in soccer training. However, it is recommended that this program only be used during preseason training sessions rather than immediately before matches.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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IMPLEMENTING A NEW METHOD FOR TEACHING FREESTYLE AND BACK-STROKE TECHNIQUE IN HIGH EDUCATION PE-A COMPARATIVE STUDY

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Background: The integration of technology into physical education has introduced new methods for teaching motor skills, including swimming techniques. Understanding the effectiveness of multimedia content compared to traditional instruction methods is essential for improving pedagogical practices in higher education. This study aimed to evaluate the effectiveness of two instructional approaches – practical demonstration and video presentation—in the acquisition of swimming motor skills.

Methods: A total of 98 students were randomly assigned to either a demonstration group (N=43) or a video group (N=55). Using a newly developed evaluation scale, participants were assessed on three components of swimming technique: start, technique execution, and turn. A two-way 2×3 factorial ANOVA was conducted to examine the effects of instructional method (between-subject factor: Group) and technical component (within-subject factor: Element) for both crawl and backstroke.

Results: For both swimming styles, the main effect of instructional group was not statistically significant (crawl: $F=0.596$, $p=0.442$, $\eta^2=0.006$; backstroke: $F=0.002$, $p=0.962$, $\eta^2=0.000$), indicating no difference between demonstration and video instruction. However, the effect of technical component was significant for both crawl ($F=16.121$, $p<0.001$, $\eta^2=0.144$) and backstroke ($F=26.364$, $p<0.001$, $\eta^2=0.215$). Post hoc analysis revealed significant differences between elements within each swimming style ($p<0.01$).

Conclusions: The findings suggest that both instructional approaches are equally effective in teaching swimming techniques, supporting the inclusion of multimedia tools in physical education. These results support the development of modern, technology-supported teaching strategies for motor skill acquisition.

Introduction

Learning is a focal point of almost all anthropological and educational disciplines, especially educational sciences. Physical education is no exception, and the learning process is studied from various aspects in different areas of kinesiology, from education and sports to recreation and kinesitherapy [1]. Consequently, young people are the backbone of society in many social environments, with students being the most numerous among them. Therefore, education is an indispensable segment of every academic community. In addition to those mentioned above, we are witnessing new social and technological advancements and challenges. Education of children and youth from preschool to higher education through physical education (PE) classes and other kinesiology activities, such as recreation and sports disciplines, was required to adapt during this challenging period by implementing new learning methods and technologies [2–8]. Therefore, it is necessary to create conditions encouraging as many children as possible to participate in the system of exercises in educational institutions [9–11].

Furthermore, the period of higher education is particularly interesting because the number of teaching iterations is smaller compared to PE classes in primary and secondary schools. It is also important to note that in this final phase of education, students have developed self-learning abilities, and it is crucial to provide them with methods to enhance their success in this education component as well.

At the Faculty of Kinesiology, teaching the subject of Sports Swimming is part of the education of future educational experts. Due to the medium in which this activity takes place, it requires a unique method of information transfer between teacher and student [12]. Environmental factors complicate the exchange of information (head submerged in water, swimming cap, ambient noise), leading to errors in technique performance [13]. Increasingly, various technologies such as smartphones, laptops, and tablets are being introduced in physical education classes to improve information transfer [12,14,15].

Learning swimming techniques through video recordings is more effective than using verbal and visual techniques, such as comments, gestures, and demonstrations, as well as the importance of distance education, supported by positive student attitudes. Additionally, the results of previous studies indicate that swimming learning programs using additional feedback, such as mobile devices, can be beneficial for students and are recommended for teachers [16–19].

Regarding the above, some studies do not support these claims and did not find significant differences in different teaching methods for swimming relay performance [20,21].

Technological progress compels us to change, and modern content offers contemporary working methods. Multimedia technologies thus allow a new approach to teaching content. With the significant increase in the use of new interactive digital content in education, today's students have the option of fast and functional learning. Using technological tools such as laptops, tablets, smartphones, and smartwatches provides teachers and students with a range of new aids that have the potential to make learning more diverse. Therefore, the existence and progress of multimedia continuously set new social changes. As a result, the assistance of technology in teaching is becoming an indispensable component of the teaching process [22,23]. In the field of physical exercise or sports, the situation is very similar, and the use of technology and technological aids has become commonplace [24,25]. Physical education teachers and coaches are increasingly relying on modern multimedia systems in their practice. Technological aids have become an integral part of the teaching process.

Modern education development involves incorporating technology into teaching from both the teacher's and student's perspectives. Introducing new teaching methods enables faster student progress, and it is necessary to implement new content or tools to make the educational system more effective [26]. It can be said that it is equally crucial for the student to correctly adopt a motor pattern as it is for the teacher to choose the appropriate working method. Scientists, on the other hand, aim to examine the effects of modern methods and prove their actual effectiveness in practice. In recent decades, with the advent of science and new technologies in everyday life, significant changes have occurred in teaching and learning methods [26]. Personal computers are widely used in elementary schools and universities today. Young generations are inclined to work with new information technologies; therefore, computer-based education and the introduction of multimedia tools in the educational process generally result in a positive response from students.

This study aimed to assess whether video-based instruction is as effective as traditional practical demonstration in teaching swimming techniques to university students, thereby evaluating the applicability of multimedia tools in higher education physical education contexts.

Material and Methods

Study design

This was a comparative study. It was conducted at the Faculty of Kinesiology during the fourth semester, which lasted from the end of February until the end of June. All students were required to undergo physical examinations before enrolling in their first year of college. An analysis of the entire population of second-year kinesiology students from the Faculty of Kinesiology who underwent physical examination during the specified period was conducted. The data were collected by experts at the University of Zagreb, Faculty of Kinesiology.

Participants and variables

A consecutive sampling method was applied in this study. The examination was conducted on kinesiology students attending the Sports Swimming course. No students in the experiment participated in swimming school or were involved in competitive swimming, ensuring that the groups did not differ prior to the start of the study. Students who had prior swimming training were excluded from the sample. The study adhered to the principles of the Helsinki Declaration, ensuring that participants could withdraw from measurements at any time without penalties. The research was conducted based on the decision of the Faculty Council, Class: 643-02/21-13/006, Reg. No.: 2181-205-02-01-21-001.

The participants were randomly divided into approximately equal-sized groups ($N_1=43$; $N_2=55$). Each day, both groups attended classes. Each group had 45-minute sessions. The first group was subjected to a practical demonstration by an experienced swimmer who demonstrated every segment of the taught swimming practice two times. While showing it for the first time, students were standing outside, and while demonstrating it the second time, they watched from underwater. The second group had visuals on a TV screen. Two visuals were shown for each segment of a taught swimming practice. The first visual was above water, and the second was underwater. The professor explained the practice to both groups before the demonstration. The experiment was conducted at the swimming pool from the end of February to the end of June, three times a week for 45 minutes.

Participants were evaluated in the following variables to assess swimming performance: Freestyle Start (FS), Freestyle Technique (FT), Freestyle Turn (FTr), Backstroke Start (BS), Backstroke Technique (BT), and Backstroke Turn (BTr). The final score for each variable was calculated as the average of the scores assigned by all evaluators. All abbreviations are defined at first use and used consistently throughout the manuscript.

Experimental procedure

Variables were assessed during a 50-meter freestyle and backstroke swim to evaluate performance. All participants were given a clear explanation of the task before attempting the 50-meter distance. At the sound of a whistle, each participant would step onto the starting block or jump into the water, followed by assuming the starting position. Then, the "Get set" command was given, followed by another whistle signal for the start of the swim. Each performance was recorded on video and evaluated by each of the five judges.

Therefore, the variables for assessing swimming performance are the scores assigned by the judges to each participant for executing each observed segment (Start, Technique, and Turn) for the freestyle and backstroke swimming techniques. The experiment was conducted by competent swimming experts (five of them) who were evaluators. Swimming was performed according to the rules of the global swimming governing body, the *World Aquatics* rules. One group received a live demonstration of the performance, while the other group was taught through video clips. Equal time was allocated to both demonstration and video viewing before practicing the technique, and the exercises were carried out in a pre-defined order for both groups. The same professor was present at each session.

In accordance with the curriculum of the Sports Swimming course, a pre-defined number of repetitions for each exercise and the distance swum was established. Each technique was taught/practiced for eight sessions of 45 minutes, with two sessions allocated to leg work, two to arm work, two to coordination, and two to start and turn execution. The first session focused on learning, while the second focused on practice. In the first session, the first group learned legs, arms, coordination, and start and turn with the help of a demonstrator in the water, while video clips of specific exercises and techniques were shown to the second group, with verbal explanations from the professor for both groups.

Upon completing each instructional topic, all students had a test. Their knowledge of each technique and its components was assessed; students had to perform a proper start, swim 50 meters with a turn at 25 meters, and complete the swim correctly. This procedure was repeated to assess both swimming techniques. Equal conditions were ensured for all participants, including water and air temperature, conducting lessons in the same pool, starting from the same block, and having the same starter and video recorder.

Before the experiment, the criteria for evaluating each swimming technique were defined and described using a constructed 9-point Likert scale (1-9). Prior to the main experiment, a pilot study was conducted on a smaller sample of students to verify the clarity of instructions, the applicability of the evaluation criteria, and to calibrate the evaluators with the 9-point Likert scale. All five evaluators participated in a joint training session, during which they reviewed and discussed the assessment criteria and evaluated several pilot video recordings not included in the main study. This process aimed to align their understanding and application of the 9-point Likert scale for each segment of the swimming technique. Each evaluator then independently assessed additional pilot performances to ensure consistency further. All main study evaluations were performed independently, without discussion among evaluators. The evaluators each had a minimum of five years of experience in swimming coaching or judging swimming technique. Therefore, the evaluators were familiarized with the assessment criteria for each segment of the swimming technique. Errors on the scale were precisely elaborated and determined (from arm stroke phases to leg work, breathing, and coordination). For each performance segment, the following assessments were made for each technique: Start from the starting block, Technique of swimming 50 meters, and Turn. Each previously mentioned element was taught and evaluated based on the specified criteria for each specific swimming performance segment, developed through the collaborative efforts of a group of experts working on the scoring system. This scale is the most suitable choice regarding sensitivity. The basic differentiation criteria are described in Table 1.

Table 1. The basic differentiation criteria

Score	Description
9	Implies fluidity, smoothness, and maximum efficiency in executing each swimming technique in all phases of the start, technique, and turn; optimal coordination structure of arm, leg, and breathing work; low energy requirement; and very high aesthetic and efficient level.
8	Implies demonstration of the swimming technique in all phases of the start, technique, and turn where there are obstacles to achieving smooth and fluid execution with maximum efficiency, or execution where the optimal coordination structure of arm, leg, or breathing work in performing a particular element and/or body position is not achieved; low energy requirement, and high aesthetic and efficient level.
7	Implies demonstration of the swimming technique in all phases of the start, technique, and turn, where there are errors that do not significantly affect the coordination structure of arm, leg, or breathing work in performing a particular element and/or body position; low energy requirement, and very good aesthetic level.
6	Implies demonstration of the swimming technique in all phases of the start, technique, and turn, where errors significantly affect the coordination structure of arm, leg, or breathing work in performing a particular element and/or body position; performance at a good aesthetic and efficient level.
5	Implies demonstration of the swimming technique in all phases of the start, technique, and turn where there are errors that significantly impact the coordination structure of arm, leg, or breathing work in performing a particular element and/or body position; the performance is not fluid, with errors in multiple phases, but still at a good aesthetic and efficient level.
4	Implies demonstration of the swimming technique in all phases of the start, technique, and turn, which leads to partial disruption of the coordination structure of arm, leg, or breathing work in performing a particular element, with frequent irregularities and errors in execution and an unfavourable body position; errors in almost all phases, performance at a lower aesthetic and efficient level.
3	Implies demonstration of the swimming technique in all phases of the start, technique, and turn, which leads to a disruption of the coordination structure of arm, leg, or breathing work in performing a particular element, with continuous irregularities and errors in execution and poor body position; errors in almost all phases, performance at a poor aesthetic and efficient level.
2	Implies demonstration of the swimming technique in all phases of the start, technique, and turn, which almost leads to the impossibility of coordinating arm, leg, or breathing work in performing a particular element, with continuous irregularities and errors in execution and very poor body position; errors in almost all phases, performance at a poor aesthetic and efficient level.
1	Implies the inability to demonstrate the execution of the swimming technique in all phases of the start, technical execution, and turn, or the inability to complete the assigned segment, with deviations in segments that, according to World Aquatics rules, are categorized as disqualification errors.

Statistical analysis

All data were presented as mean±standard deviation. For all variables, Cronbach's Alpha and inter-item correlation were calculated as a measure of internal consistency. Two-way 2×3 factorial ANOVA was applied to examine the main effects of between-subjects factors *Group* (Demonstration and Video) and *Element* (Start, Technique, and Turn), and their interaction effect. Test statistics (F), level of statistical significance (p), and partial eta squared (partial η^2) as effect site assessment were calculated. Partial eta squared equal 0.01, 0.06, and 0.14 are interpreted as small, moderate, and large effect sizes, respectively.

The normality of the distribution of all variables was tested using the Kolmogorov-Smirnov test with Lilliefors' correction. Descriptive statistics indicators were calculated for all variables: mean, standard deviation, minimum, maximum, and coefficient of variation as a measure of relative variability. Type I error was set at $\alpha=5\%$. The Statistica 14.0.0.15 package was used for the data processing [27].

Results

Table 2 presents reliability indicators for all observed variables, first group and second group, i.e., judges in the elements of Start, Technique, and Turn for both techniques, freestyle, and backstroke. The calculated reliability parameters are Cronbach's Alpha coefficient and inter-item correlation.

Table 2. Reliability indicators

	All		G1		G2	
Variable	**Cα**	**IIR**	**Cα**	**IIR**	**Cα**	**IIR**
FS	0.86	0.58	0.93	0.75	0.87	0.59
FT	0.91	0.66	0.91	0.68	0.91	0.68
FTr	0.94	0.76	0.94	0.77	0.94	0.77
BS	0.93	0.74	0.94	0.78	0.92	0.72
BT	0.90	0.66	0.93	0.76	0.88	0.60
BTr	0.94	0.78	0.93	0.75	0.95	0.81

FS – Freestyle Start; FT– Freestyle Technique; FTr – Freestyle Turn; BS – Backstroke Start; BT – Backstroke Technique; BTr – Backstroke Turn. Cronbach's Alpha coefficient (Cα) and inter-item correlation (IIR) for all subjects (All), first group; *Demonstration* (G1) and second group; *Video* (G2)

The results shown in Table 2 indicate that the reliability indicators are relatively high, particularly regarding Cronbach's Alpha. The inter-item correlation also gives moderate to high values in terms of reliability.

Table 3 shows the parameters of descriptive statistics of both groups for all the observed variables.

Table 3. Parameters of descriptive statistics

Variable	Grozup 1				Group 2			
	Mean±SD	**Min**	**Max**	**CV**	**Mean±SD**	**Min**	**Max**	**CV**
FS	26.16±10.44	5.00	43.00	39.90	27.80±7.73	9.00	43.00	27.81
FT	26.23±8.31	7.00	42.00	31.69	27.18±7.32	7.00	44.00	26.93
FTr	22.58±11.11	5.00	43.00	49.18	23.78±9.58	5.00	45.00	40.30
BS	20.05±11.37	5.00	43.00	56.70	21.76±10.79	5.00	45.00	49.59
BT	16.21±9.64	6.00	39.00	59.47	14.67±8.42	5.00	35.00	57.40
BTr	15.86±10.38	5.00	42.00	65.45	15.95±10.52	5.00	45.00	65.97

FS – Freestyle Start; FT– Freestyle Technique; FTr – Freestyle Turn; BS – Backstroke Start; BT – Backstroke Technique; BTr – Backstroke Turn. M – mean; SD – standard deviation; Min – minimum value; Max – maximum value; CV – coefficient of variation

Table 3 shows that all observed parameters confirm a normal data distribution for all listed variables. However, it should be noted that the mean ± standard deviation for the variable backstroke turn in Group 1 is 15.86±10.38, while the mean ± standard deviation for the variable backstroke technique in Group 2 is 14.67±8.42.

Regarding crawl, two-way factorial ANOVA identified no significant main effect of factor *Group* ($F_{96,1}=0.596$; $p=0.442$; $\eta^2=0.006$), whilst the main effect of factor *Element* appeared to be significant ($F_{96,2}=16.121$; $p<0.001$; $\eta^2=0.144$). Bonferroni correction revealed differences between Start and Turn and Technique and Turn ($p<0.01$, $p<0.01$). Interaction effect *Group* × *Element* appeared insignificant ($F_{192,2}=0.109$; $p=0.897$; $\eta^2=0.001$).

Furthermore, for backstroke, ANOVA revealed no significant main effect of factor *Group* ($F_{96,1}=0.002$; $p=0.962$; $\eta^2=0.000$). Conversely, the main effect of factor *Element* appeared to be significant ($F_{96,2}=26.364$; $p<0.001$; $\eta^2=0.215$). Bonferroni correction revealed differences between Start and Technique ($p<0.01$) and Start and Turn ($p<0.01$). Interaction effect *Group* × *Element* appeared insignificant ($F_{192,2}=1.900$; $p=0.152$; $\eta^2=0.019$).

Discussion

Results related to metric characteristics indicate that, although the analysis of variance shows significant differences among judges, particularly in the evaluation of backstroke technical performance, a detailed review reveals a high level of consistency in their assessments. From the overall swimming technique, the most differences are found in the technical performance between the observed swimming techniques. The results clearly demonstrate the high reliability of the measurement instrument. Results pertaining exclusively to the first group clearly indicate the high reliability of the measurement instrument, which is also evident in the results for the second group.

In the initial section of the discussion, the parameters of descriptive statistics, which also confirm the normal distribution of data for all listed variables, will be addressed. However, it is evident that the backstroke turn and backstroke start variables deviate in mean and standard deviation. This deviation in the backstroke occurs due to the inherent complexity of the backstroke technique, as explained further in the text.

A statistically significant difference was identified between the freestyle elements, which was expected given the biomechanical components of movement used in executing these swimming structures. Although the elements of the freestyle start and the turn are somewhat similar in their structure, particularly in the phases of underwater swimming, surfacing, and the beginning of swimming, differences were found between them. Speed in the air phase and the average horizontal acceleration are the variables most associated with the performance of the freestyle start in experienced swimmers [28]. These components are certainly not integral parts of the Technique and Turn element; therefore, they logically contribute to the existence of differences.

Although the technique of swimming is an integral part of the turn phase, as the turn itself consists of the approach to the wall and the beginning of swimming, where the start of swimming is determined at the moment when the legs begin to work and ends when the hands complete the second stroke, the freestyle turn is an extremely complex motor skill that involves many different actions performed consecutively and quickly [29]. For example, it takes about 1.1 seconds from the start of the rotation to the moment when the feet leave the wall. During this short time, the swimmer decelerates, changes position, and generates the highest possible speed in the completely opposite direction by applying the push-off force from the wall. Immediately after this follows the underwater phase, which includes gliding and underwater swimming [30]. Therefore, different motor structures, such as technical execution or turn, are expected to result in different effects.

As expected, the results of the two-factor analysis of variance for backstroke swimming have confirmed significant differences between the elements, specifically between the backstroke start and backstroke technique and between the backstroke start and backstroke turn.

When observing the backstroke start and backstroke technique, these are two completely different motor movements. Although the backstroke start includes the phase of beginning swimming within its structure, therefore significant differences were found between these elements. Furthermore, it is interesting that despite the backstroke start and backstroke turn sharing the same phases – pushing off the wall, underwater swimming, surfacing, and beginning swimming – a difference was found between these two elements.

Nevertheless, the analysis revealed no significant differences between the two groups, i.e., two different teaching methods for the observed swimming techniques and their elements. This is likely because both models employed a combination of visual demonstration and verbal explanation by the instructor. These findings are important for implementing new methods while emphasizing that traditional approaches have proven to be highly reliable and effective.

During the start, a swimmer needs to minimize hydrodynamic drag to maintain movement through the water until the point of surfacing and beginning swimming. Two key factors influencing the efficiency of the underwater phase are hydrodynamic resistance and the initial push-off speed [31]. Also, the force produced during the underwater phase of the backstroke start is the greatest hydrodynamic drag force that can be generated, which slows the body's movement after the initial push-off [32,33]. Additionally, the underwater rotation speed during the backstroke turn is a crucial variable associated with the swimmer's skill level [34].

These findings are significant for teaching the mentioned swimming techniques and their individual elements, as they provide a better understanding of the key areas that require special attention during the learning process. Therefore, the approach of coaches or teachers toward each student must be individualized and tailored to their specific needs. This enables a detailed analysis and a focus on aspects that require further attention.

These methods can also be applied in sports and various other educational institutions, including universities with mandatory physical education classes or courses in sports and recreation led by teachers [35-39].

Strengths of the Study

When discussing the strengths of this study, it aimed to evaluate the effectiveness of two distinct approaches to teaching swimming skills among higher education students. After instruction, swimming performance was assessed using a newly developed set of criteria.

The findings suggest that integrating modern multimedia content into educational practices can enhance teaching methods in PE. The study emphasizes the importance of adapting teaching strategies to leverage technology for improved learning outcomes in swimming techniques. Moreover, it is crucial to incorporate modern technology and video analysis into the teaching process for beginners and in educational contexts to facilitate the acquisition, development, and refinement of specific motor skills. This approach provides insights into the degree of skill development and ensures the creation of guidelines for further skill enhancement.

Limitations of the Study

Several limitations of this study should be noted. A major constraint was the limited sample size, highlighting the need for future studies to include a larger and more diverse population of participants (e.g., children or students of varying age groups). It is also advisable to consider gender differentiation by including male and female participants in the sample. Additionally, expanding the range of variables, such as psychological dimensions, is recommended to gain a deeper understanding of the observed issues.

Another significant limitation of the study was the impact of the COVID-19 pandemic, along with the accompanying epidemiological measures in place at the time. This situation led to the exclusion of certain participants due to the need for isolation. However, this challenge also provided an impetus for the practical application and development of modern technology, emphasizing its integration into the educational system.

In light of these limitations, future research should consider these recommendations to establish a robust conceptual framework, thereby facilitating more comprehensive and reliable conclusions.

Conclusions

The results of this study indicate that there is no significant difference in the effectiveness of traditional demonstrative instruction versus video-based teaching in the acquisition and refinement of swimming skills. This supports the growing relevance of integrating multimedia approaches into physical education. The findings reinforce the potential of modern technologies in educational settings, particularly in teaching practical motor skills. As technology continues to evolve, its thoughtful application in pedagogical frameworks becomes increasingly valuable.

Practical implication

From a practical standpoint, these results suggest that multimedia tools can be a valid alternative or supplement to traditional instruction in physical education. Their application can improve accessibility, engage digital-native students more effectively, and provide standardized instructional content for swimming educators and sports professionals.

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THE RELATIONSHIP BETWEEN DAILY STEP COUNT AND ALL-CAUSE MORTALITY – UMBRELLA REVIEW

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Background: This umbrella review assesses the relationship between daily step count and all-cause mortality. The aim is to approximate the ideal number of steps per day and provide insights into improving public health.

Methods: The inclusion criteria focused on studies analyzing daily step count and health outcomes, specifically mortality. Databases searched included PubMed and Scopus from January 2020 to December 2024. Search terms included "daily steps," "mortality," and "health." Risk of bias was assessed using PEDro scale.

Results: Of 389 articles, 17 met the inclusion criteria, encompassing over 200,000 participants. An increase in daily step count was consistently associated with reduced all-cause mortality. Significant benefits were observed with 8,000–10,000 steps per day. The review highlighted variations in participant characteristics, step measurement methods, and geographic distribution.

Conclusions: The evidence has limitations, such as differences in how steps were measured, variations in participant groups, and study locations, which may affect the results. Some studies also lacked consistent reporting, leading to potential bias. Future research should address these gaps to strengthen the overall findings.

Introduction

A sedentary lifestyle is a significant factor contributing to the decline in health as well as the quality and length of life. A simple and accessible remedy to address this global issue is walking, one of the most basic forms of physical activity. Walking can be performed almost anywhere, requires no specialized equipment, and does not demand advanced athletic skills, making it widely accessible to everyone. The number of steps taken per day serves as an objective indicator of physical activity, which can be easily monitored using increasingly popular devices and applications such as pedometers, accelerometers, smartphones, smartwatches, and step counters [1,2].

Numerous studies have shown a relationship between the daily step count and overall mortality risk, particularly in the context of cardiovascular diseases and cancers. This relationship suggests that the more steps taken per day, the lower the risk of death from various causes [2]. However, there is no consensus on specific numerical values for daily step counts recommended for different age and gender groups, above which the risk of death from any cause begins to decline significantly. Furthermore, no official guidelines or recommendations define such thresholds [3]. Developing such guidelines is crucial because walking, due to its simplicity, provides an effective way for healthcare professionals to encourage patients to engage in physical activity, and daily step count serves as a practical metric for monitoring activity levels in patients.

The widely promoted claim that 10,000 steps per day is the sole threshold for achieving health benefits is misleading, as such effects can be observed with lower step counts [2, 4, 5, 6]. Despite the availability of numerous studies demonstrating the relationship between daily step count and mortality from various causes, there is still a lack of conclusive findings to determine a general minimal daily step recommendation. To create cohesive public health recommendations, it is necessary to compare study populations, methods of physical activity measurement, and observation periods used in research, while highlighting the differences among them.

Our umbrella review analyzes cohort studies and systematic reviews, focusing on:

1. Determining the relationship between daily step count and mortality from various causes.
2. Establishing a minimum protective threshold for the number of steps per day.
3. Identifying and presenting differences between studies, including those related to gender, age, measurement methods, and observation periods.

The findings of this review may serve as a valuable source of information for both healthcare professionals and their patients, enabling more informed and accurate monitoring of physical activity levels. This, in turn, can improve health status and reduce the risk of mortality from any cause.

Materials and Methods

Protocol: This umbrella review was conducted following the latest PRISMA guidelines [7]. As it synthesizes data from previously published studies, no ethical approval was required.

Data Sources and Search Strategy: We performed a comprehensive literature search in PubMed and Scopus databases, covering the period from 2020 to 2024. The search strategy included the following keywords: “daily steps,” “mortality,” and “health.”

Study Selection

Inclusion criteria:

a) Research examining the association between daily step count and health outcomes or mortality risk.
b) Studies involving participants aged 18 years and older,
c) Studies that provided detailed demographic data, including gender distribution and total number of participants,

Exclusion criteria:

a) Studies involving professional athletes,
b) Studies lacking critical data, such as step count or methodological details,
c) Research focusing on non-step-based physical activities (e.g., high-intensity interval training, cycling).

Two independent reviewers (JD and KZ) screened titles and abstracts for eligibility. Full-text articles were assessed based on the inclusion and exclusion criteria.

Data Extraction and Management: Data were extracted by two reviewers independently using a pre-defined extraction form. Extracted data included study characteristics, participant demographics, step count metrics, health outcomes, and mortality data. The literature search was limited to articles published in English or Portuguese (one article). The review was also restricted to research performed on humans.

Risk of Bias Assessment: For each article, the risk of bias was independently assessed by the same investigators using the assessment of risk of bias in cohort studies on the PEDro Scale. The risk of bias in each study was classified as ‘good’, ‘fair’, or ‘poor’. The results of this assessment are presented in Table 1.

Table 1. Risk of bias in PEDro Scale

Article	Eligibility	Randomization	Allocation Concealment	Baseline Similarity	Blinding of subjects	Blinding of Investigators	Unbiased Outcome Assessment	Measures >=85%	Intention to Treat analysis	Between intervention statistical comparison	Point Measures	Total Score
Saint-Maurice et al. (2020) [5]	1	1	1	1	0	0	1	1	1	1	1	7 (fair)
Del Pozo Cruz et al. (2022) [3]	1	1	1	1	0	0	1	1	1	1	1	7 (fair)

Ahmadi et al. (2024) [8]	1	1	0	1	0	0	1	1	0	1	1	5 (poor)
Hansen et al. (2020) [1]	1	1	0	1	0	0	1	1	1	1	1	6 (fair)
Paluch et al. (2021) [9]	1	1	0	1	0	0	1	1	1	1	1	6 (fair)
Watanabe (2023) [10]	1	1	0	1	0	0	1	1	0	1	1	5 (poor)
Masahiro Nishi et al. (2024) [11]	1	1	0	1	0	0	1	1	1	1	1	6 (fair)
Mohd Fakhree Saad et al. (2021) [12]	1	1	0	1	0	0	1	1	1	1	1	6 (fair)
Rômulo José Mota Júnior et al. (2021) [13]	1	1	0	1	0	0	1	1	0	1	1	5 (poor)
Kosuke Inoue et al. (2023) [14]	1	1	0	1	0	0	1	1	1	1	1	6 (fair)
Banach et al. (2023) [6]	1	1	1	1	0	0	1	1	1	1	1	9 (good)
Paluch Amanda et al. (2022) [4]	1	1	1	1	1	0	1	1	1	1	1	10 (good)
Stens Niels et al. (2023) [15]	1	1	1	1	0	1	1	1	1	1	1	10 (good)
Rodriguez-Gutierrez et al. (2024) [16]	1	1	1	1	0	0	1	1	1	1	1	9 (good)
Paluch et al. (2023) [17]	1	1	1	1	1	1	1	1	1	1	1	11 (good)
Hall et al. (2020) [18]	1	1	1	1	0	0	1	1	1	1	1	9 (good)
Sheng et al. (2021) [2]	1	1	1	1	0	0	1	1	1	1	1	9 (good)

Author Contributions:

Each stage of the review process was conducted by designated authors as follows:

- Database search and initial screening: [KZ, JD]
- Full-text review and data extraction: [KZ, JD]
- Risk of bias assessment: [GK, MR]
- Final review and consensus: [KZ, JD, GK, MR]

Results

Figure 1 was developed in accordance with PRISMA guidelines and illustrates the selection process of studies for this systematic review. Of the 389 initially identified studies, 15 duplicates and 279 publications were excluded for various reasons. Full texts of the remaining 95 studies were reviewed, resulting in the exclusion of 2 combined articles and 76 studies unrelated to the topic. The systematic review analyzes the remaining 17 selected articles, which are presented in Tables 1 and 2. Table 1 outlines the characteristics of prospective cohort studies, while Table 2 details the characteristics of systematic reviews.

A total of 4,840 participants (2,435 women) from the USA were included in a study that demonstrated that performing 9,124 steps per day over 7 days was associated with lower mortality from cardiovascular diseases (CVD) and cancer. During a 10.1-year follow-up, 1,165 deaths were recorded, including 460 from CVD and 283 from cancer [6]. In another cohort study, 78,500 participants (43,418 women) from the United Kingdom who performed an average of 7,198.2 steps per day over 7 days were observed. The findings revealed that performing approximately 10,000 steps per day resulted in a lower risk of mortality. Over 7 years, there were 2,179 deaths, including 664 due to cardiovascular diseases and 1,325 due to cancer [4]. Similarly, a study in the United Kingdom involving 72,174

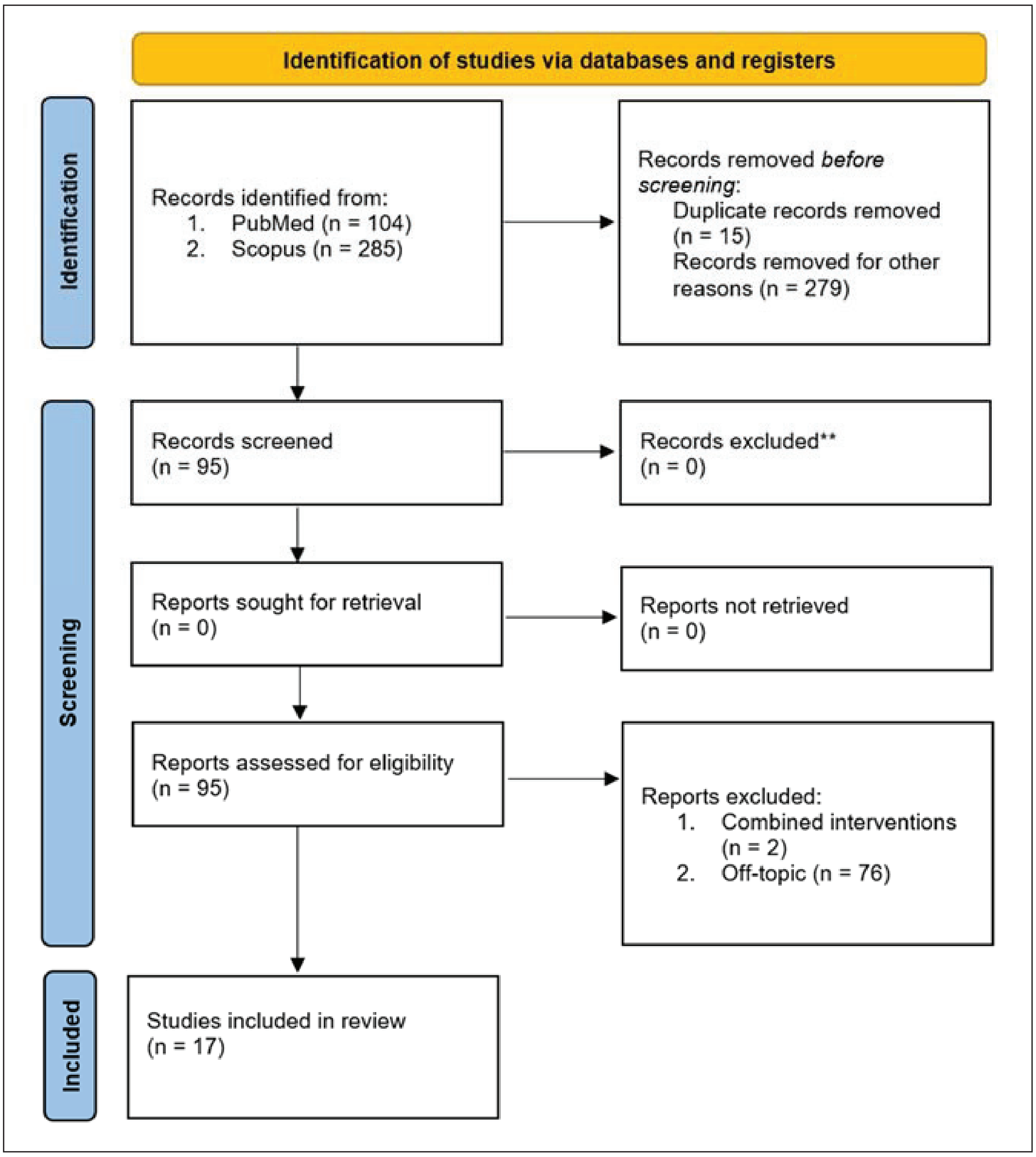

Figure 1. PRISMA 2020 flow diagram of studies included in the review

participants (57.9% women) showed that the minimum threshold for health benefits was 4,000–4,500 steps per day, while the lowest mortality risk was observed with 9,000–10,500 steps per day. Participants performed an average of 6,222 steps per day over 7 days, and, during a 6.9-year follow-up, 1,633 deaths were recorded [8]. A Norwegian study involving 2,183 participants (53% women) found that increasing the daily step count by 2,200 steps reduced mortality risk by 48%. The median step count in the highest quartile was 11,467 steps per day. Over a 9.1-year period, 119 deaths from any cause were recorded [1]. Another analysis, of 2,110 middle-aged participants (1,205 women) from the USA, who performed an average of 9,146 steps per day over 7 days, recorded 72 deaths over a 3.38-year period. Individuals who performed approximately 7,000 steps per day had lower mortality rates [9]. A Japanese study with 4,165 participants (2,028 women) aged over 65 found that individuals with frailty needed to perform more daily steps to achieve comparable benefits in reducing mortality risk as those without frailty. The fourth quartile recorded the highest daily step count of 7,502, with a follow-up period of 4 days [10]. Another Japanese study analyzed 4,957 participants (2,592 women) who performed between 9,000 and 11,000 steps per day (on average 5,650 steps). Participants reported improved health status and reduced functional limitations [11]. A 12-week observational study conducted in Malaysia involved 109 older adults (66 women) with overweight conditions. Participants performed an average of 3,571 steps per day, which resulted in a reduction in body weight

(-2.20 kg) and waist circumference (-2.91 cm) [12]. In a study of 150 Brazilian teachers (108 women), performing approximately 10,000 steps per day over 8 days led to improvements in BMI and LDL cholesterol levels compared to less active colleagues [13]. Finally, a study conducted in the USA with 3,101 participants (1,583 women) who performed 8,000 steps per day over 7 days found a lower risk of mortality. During the 10-year follow-up, 587 deaths from any cause were recorded [14].

A large-scale analysis of data collected between 1998 and 2015 from Australia, the UK, the USA, Japan, Norway, and Spain included 17 cohort studies with a total of 226,889 participants (110,949 women). Participants in successive quartiles performed approximately 1,000 additional steps daily: Quartile 1 – 4,038 steps/day, Quartile 2 – 6,201 steps/day, Quartile 3 – 7,094 steps/day, and Quartile 4 – 11,275 steps/day. Over a mean 7.1-year follow-up, 7,574

Table 2. Characteristics of the included prospective cohort studies

STUDY	YEARS OF STUDY	LOCATION	PARTICIPANTS	MONITORING PERIOD	STEPS/DAY	ENDPOINTS	FOLLOW UP
Saint-Maurice et al. (2020) [6]	2003-2006	USA	n – 4840 mean age – 56.8 years male – 2405 female –2435	7 days	Median daily steps count was 9124.	All-cause mortality: 1165 (CVD - 406, cancer - 283)	10,1 years
Del Pozo Cruz et al. (2022) [4]	2013-2015	England, Scotland, Wales	n - 78 500 mean age – 61 years male – 35 082 female – 43 418	7 days	Median daily steps count was 7198.2.	All-cause mortality: 2179 (CVD - 664, cancer - 1325)	7 years
Ahmadi et al. (2024) [8]	2013 - 2015	UK	n - 72 174 mean age - 61.1 ±7.8 years male – 42.1% female – 57.9%	7 days	Median daily steps count was 6222 (4102 - 9225).	All-cause mortality: 1633	6.9 (±0.8) years
Hansen et al. (2020) [1]	2008-2009	Norway	n – 2183 mean age – 57 years male – 47% female – 53%	7 days	Median daily steps across ascending quartiles were: Q1 - 4651 Q2 - 6862 Q3 - 8670 Q4 - 11 467.	All-cause mortality: 119	9.1 years
Paluch et al. (2021) [9]	2005-2006	USA	n – 2110 mean age – 45.2 years male – 905 (42.9%) female – 1205 (57.1%)	7 days	Median daily steps count was 9146 (7307-11162).	All-cause mortality: 72	10.8 years
Watanabe (2023) [10]	2011-2013	Japan	n – 4165 age: > 65 years male – 2137 (51.3%) female – 2028 (48.7%)	4 days	Q1 - 1786 Q2 - 3030 Q3 - 4452 Q4 - 7502	All-cause mortality: 113	3.38 years
Masahiro Nishi et al. (2024) [11]	2019-2023	Japan	n - 4957 mean age - 60 years male - 2365 female - 2592	nd	Median daily steps count was 5650 (3332–8452).	More daily steps improved health self-assessment and reduced reported limitations, but the effect stabilized above 11,000 steps.	4 years
Mohd Fakhree Saad et al. (2021) [12]	2019 -2020	Malaysia	n – 109 [elderly people with BMI ≥25.0 kg/m²] mean age - 65.73±5.57 years male - 43 female – 66	12 weeks	The goal was to gradually increase steps by 500 per week over 12 weeks until exceeding 7,000.	Post-intervention, daily steps increased by 3,571, with reductions in weight (-2.2 kg), BMI (-0.94), body fat (-3.52%), visceral fat (-1.29%), waist (-2.91 cm), and a muscle gain (+1.67%).	nd

Rômulo José Mota Júnior et al. (2021) [13]	2020	Brazil	n – 150 [teachers with at least 3 years of continuous work, without taking sick leave or maternity leave, and not being pregnant] mean age: G1 – 41 years G2 – 34 years male - 42 female - 108	8 consecutive days	Teachers were divided into 2 groups (G1 < 10000 steps/ day and G2 > 10000 steps/ day) G1: n = 87 G2: n = 63	G1: BMI – 25,7 (18,8-40,3) TC – 115 (40-350) LDL-C- 109 (57-196) G2: BMI – 24,3 (17,2-36) TC – 103 (38-360) LDL-C- 99 (61-167)	nd
Kosuke Inoue et al. (2023) [14]	2005-2006	USA	n - 3101 mean age - 50.5 years male - 1518 female - 1583	7 days	632 (20.4%) did not take 8000 steps or more any day of the week, 532 (17.2%) took 8000 steps or more 1 to 2 days per week, and 1937 (62.5%) took 8000 steps or more 3 to 7 days per week.	All-cause mortality: 587	10 years

nd – no data; CVD – cardio vascular disease

deaths were recorded, including 1,884 attributable to cardiovascular disease (CVD). The analysis concluded that an increase of 1,000 steps per day could lead to a 15% reduction in all-cause mortality, while an increase of 500 steps per day was linked to in a 7% reduction in CVD-related mortality [3]. Another study reviewed 15 cohort studies conducted between 1999 and 2018 across Europe, Australia, Japan, and the USA, involving 47,471 adults (32,336 women) who had a median daily step count ranging from 3,036 to 11,877 steps over 7 days. During a 7.1-year follow-up, 3,013 deaths from any cause were recorded. For younger participants, taking 8,000–10,000 steps per day was associated with a reduced risk of mortality, while older adults benefited from a lower threshold of 6,000–8,000 steps per day [5]. An analysis of 12 studies conducted between 2019 and 2022 involved 111,309 participants (67,676 women), who performed an average of 7,069 ± 904 steps/day over 7 days. During a follow-up period of 77.9 months, 4,854 deaths were recorded. The findings indicated that performing approximately 8,800 steps per day lowered the risk of all-cause mortality, while 7,200 steps per day reduced the risk of CVD-related mortality [15]. A separate meta-analysis of 14 cohort studies conducted between 2015 and 2024 from the UK, USA, Japan, Spain, and Norway included 119,436 adults (51.19% women), with a median step count of 6,057 steps per day over an average of 7 days. Over an 8.51-year follow-up, 5,466 deaths were recorded. The study suggested that even as few as 3,143 steps per day may be sufficient to reduce the risk of all-cause mortality [16]. Another synthesis of 8 cohort studies conducted between 2000 and 2018 included 20,253 adults (52% women) who averaged 6,911 steps/day among younger individuals and 4,323 steps/day among older individuals, measured over 3 to 7 days. During a 6.2-year follow-up, 1,523 CVD events were recorded, including 1,210 among older adults [17]. A review of literature published up to August 2019 analyzed 17 cohort studies from Australia, the USA, the UK, South Africa, China, and Japan. Study cohorts ranged from 47 to 16,741 participants (46.9% women). The average daily step count was 6,000 (ranging from 2,681 to 10,969), and studies were included if the data collection lasted at least 10 hours per day for 3–5 days. Follow-up durations for CVD and all-cause mortality ranged from 6 months to 6 years [18]. Another analysis included 16 studies published in 2021 from the UK, USA, Europe, Japan, and Australia, with a combined cohort of 147,344 participants. Among them, 12 studies on all-cause mortality involved 132,674 individuals, with 5,434 recorded deaths. The average step counts for these groups were 4,183 (Quartile 1), 6,862 (Quartile 2), and 8,959 (Quartile 3) steps per day. Additionally, 5 studies focused on CVD events with 14,670 participants and 1,082 events. Step counts for those studies were 3,742 (Quartile 1), 5,500 (Quartile 2), and 9,600 (Quartile 3). Follow-up periods ranged from 2.7 to 10.1 years. It was found that taking 8,959 steps per day reduced the risk of death by over 40% compared to 4,183 steps, while 9,500 steps per day lowered the risk of CVD events by 35% compared to 3,742 steps [2].

Table 3. Characteristics of the systematic review included in the reviews

STUDY	YEARS OF STUDY	LOCATION	PARTICIPANTS	MONITORING PERIOD	STEPS/DAY	ENDPOINTS	FOLLOW UP
Banach et al. (2023) [3]	Study start dates between 1998 and 2015.	Australia, UK, USA, Japan, Norway, Spain	17 cohort studies n - 226 889 participants (generally healthy or patients at CV risk) mean age - 64.4 ± 6.7 male – 115 940 female – 110 949	At least 7 consecutive days	1000-steps/day increment Q1 (4038 steps/day reference); Q2 (6201 steps/day); Q3 (7094 steps/day); Q4 (11,275 steps/day)	All-cause mortality: 7574 CVD mortality: 1884	7.1 years
Paluch Amanda et al. (2022) [5]	Study start dates between 1999 and 2018.	4 studies in Europe, 1 in Japan, 1 in Australia, 8 in the USA, and 1 that included data from 40 countries.	15 studies n - 47 471 adults mean age - 65.0 years male – 15 245 female - 32 226	7 days	Median steps per day from 3036 up to 11877	All-cause mortality: 3013	7.1 years
Stens Niels et al. (2023) [15]	Publishing year 2019-2022.	nd	12 studies n - 111 309 adults mean age - 62.5 +/- 5.3 years male – 43 633 female – 67 676 (mean body mass index 27.0 +/- 1.3 kg/m2)	All studies measured step count for 7 days, except for 1 cohort that measured for 2 days.	The mean daily step count was 7,069 +/- 904 steps/day.	All-cause mortality: 4854	A median follow-up period of 77,8 months
Rodriguez--Gutierrez et al. (2024) [16]	Study start dates between 2015 and 2024.	UK, USA, Japan, Spain, Norway	14 cohort studies n - 119 436 adults age: 45-78 male – 48,81% female - 51,19%	In 8 studies for 7 consecutive days, in 2 studies less than 7 days, in 1 study more than 7 days.	Median daily steps count was 6057.	All-cause mortality: 5466	8,51 years
Paluch et al. (2023) [17]	Study start dates between 2000 and 2018.	nd	8 cohort studies n – 20 152 mean age – 63,2±12.4 years male – 48% female – 52%	3-7 following days	The mean daily steps count: - for young people: 6911 (4783-9794), - for elderly people: 4323 (2760-6924)	CVD events: 1523 (1210 for elderly people)	6,2 years
Hall et al. (2020) [18]	Studies published before 1 August 2019.	Australia, USA, UK, South Africa, China, Japan	17 cohort studies n – 47 - 16 741 mean age - 49.7-78.9 years male – 53,1% female – 46.9%	in 10 studies - for 7 days, in 2 studies, for 2 months, in 5 studies - for less than 7 days (a study was valid if it lasted at least 10 h for 3-5 days)	The mean daily steps count was 6000 (2681-10969).	All-cause mortality CVD risk or events	4-10 years 6 months – 6 years

Sheng et al. (2021) [2]	Studies published before 9 July 2021.	UK, USA, Europe, Japan, Australia	16 studies (12 all-cause mortality, 5 CV disease, 1 both) n – 147 344 (132 674 all-cause mortality, 14 670 CV disease)	nd	All-cause mortality Q1 - 4183 steps/day Q2 - 6862 steps/day Q3 - 8959 steps/day CV disease: Q1 - 3742 steps/day Q2 - 5500 steps/day Q3 - 9500 steps/day	All-cause mortality: 5434 CV events: 1082	2,7-10,1 years

nd – no data; cvd – cardio vascular disease

Discussion

A 2019 study involving 109 Malaysian adults implemented a walking program in which participants gradually increased their daily step count by approximately 500 steps per week, aiming to reach an average of 7,000 steps per day by the end of the program. After 12 weeks, significant reductions in both body mass index (BMI) and visceral adipose tissue were observed in the majority of participants [12]. Similarly, a 2020 study from Brazil involving 150 actively employed teachers reported similar findings. Participants tracked their daily step counts with pedometers attached to their bodies. After tracking their steps for eight consecutive days, participants were categorized into two groups: those taking more than 10,000 steps per day and those with less than 10,000 steps per day. Anthropometric assessments showed that participants taking at least 10,000 steps daily typically had lower BMI, triglyceride, and LDL cholesterol levels [13]. These findings suggest that individuals engaging in higher daily step counts generally exhibit more favorable lipid profiles and lower BMI. Even simple activities like frequent walking significantly lower the risk of obesity, a condition that has been escalating at an alarming rate. Over the past three decades, the global prevalence of obesity increased by 27.5% among adults and 47.1% among children, which remains a worldwide concern. Each 5-unit increase in BMI above 25 kg/m^2 raises the risk of all-cause mortality by 29%, and cardiovascular disease-related mortality by 41% [19]. Furthermore, obesity can be associated with a range of comorbidities, including hepatic steatosis, hypertension, osteoarthritis, sleep apnea, and elevated risks of certain tumors such as endometrial, breast, and colorectal cancer [12,13,20-22]. Excess body weight may also lead to chronic systemic inflammation by elevating the production of pro-inflammatory cytokines, such as IL-6, IL-1, IL-8, and TNF-alpha [23,24]. Incorporating regular walking into a daily routine can be an important strategy for weight reduction, which usually leads to better general health and a lower risk of premature death.

According to data from the UK Office for National Statistics, the number of individuals aged 60 years and older is projected to increase from 17% in 2010 to approximately 23% by 2035. While this reflects significant advances in medicine contributing to increased life expectancy, older adults continue to face numerous health limitations. Among those aged 75 years and older, 30% suffer from chronic musculoskeletal disorders, while 32% report a range of cardiovascular conditions [25]. It is crucial to emphasize that aging is often accompanied by a progressive loss of skeletal muscle mass and function, which then inexorably leads to sarcopenia [26]. This process increases the metabolic cost of movement for older adults, often resulting in reduced mobility [26,27]. Maintaining recommended levels of physical activity in older adulthood may be quite challenging: only one-quarter of individuals aged 65 years and older meet the minimum recommended levels of physical activity [25]. A comprehensive meta-analysis, which examined 15 cohort studies, found that achieving at least 6,000 steps per day significantly reduces mortality in older adults [5]. A 30-minute daily walk taken for at least five consecutive days has been shown to reduce the risk of cardiovascular diseases, diabetes, dementia, and premature mortality among the elderly [28]. Encouraging older adults to gradually increase their daily physical activity and daily step count could therefore be crucial for enhancing their life expectancy.

Some studies have also examined the impact of daily step count on dysglycemia. Elevated blood glucose levels lead to the development of micro- and macroangiopathies and contribute to the progression of cardiovascular diseases, as well as long-term cardiovascular morbidity and mortality. Analyzed parameters included blood glucose levels, HbA1c, insulin resistance, 2-hour glucose, insulin sensitivity (HOMA-IR), and the occurrence of dysglycemia or type 2 diabetes. The studies reviewed do not demonstrate the effect of daily step counts on these parameters, and the results are inconsistent or show no correlation [18]. However, it is highlighted that the relationship between daily step count and incidents of dysglycemia or type 2 diabetes is inversely proportional - the risk decreases as the daily step count increases [18].

While the included studies were conducted with considerable attention to detail, several limitations warrant consideration when comparing their findings. Firstly, the participants were not only from various countries with different climates and weather conditions, as well as diverse racial and ethnic backgrounds, which could potentially influence the outcomes. Secondly, the measurement of the average daily step count was conducted using different accelerometers and pedometers, potentially leading to discrepancies in the accuracy of measurements across studies. Furthermore, the observational nature of studies may have influenced participant behavior. It is possible that some participants, knowing they need to report their average step count later, may have unintentionally increased their daily step count to appear more active. Moreover, each study exhibited differences in demographic composition, such as variations in age distribution and gender ratio, which could introduce confounding factors.

Despite these limitations, which introduce some complexity in comparing results across studies, they do not undermine the main conclusions. Regardless of differences in factors such as location or sample size, all cohort studies consistently demonstrated that a higher daily step count is associated with a significantly reduced risk of various diseases and a lower likelihood of premature mortality.

The literature review itself also faced certain limitations. Some relevant studies might have been overlooked, as the search excluded most of the non-English publications. Relying solely on indexed databases may have introduced selection bias, thereby limiting the scope of available evidence.

The studies included in the review also exhibited notable weaknesses. Many studies lacked comprehensive reporting of important details, such as follow-up periods and how they accounted for factors like exercise intensity or existing health conditions. Differences in the quality of studies further limited the reliability of the findings. Improving these areas in future research is essential for more reliable results.

The implications of this study benefit both patients and their doctors. They enable individuals to take conscious control of their health while improving both its quality and longevity. Physicians can use daily step counts as a parameter for preventing diseases such as cardiovascular disease (CVD), cancer, and all-cause mortality. The findings of this systematic review promote physical activity by highlighting walking as a simple, low-cost, and low-effort form of exercise. The popularity, widespread use, and user-friendliness of devices that measure daily step counts also support this therapeutic approach. The data presented may serve as a foundation for developing future guidelines on the recommended daily step counts, offering health benefits and protection against diseases associated with a sedentary lifestyle [2,5].

Conclusions

This systematic review presents the relationship between daily step count and all-cause mortality. The more steps taken a day, the lower the risk of death from various causes. At the same time, it should be emphasized that significant health benefits are observed even below 10,000 steps per day, particularly for older adults. The protective minimum threshold is approximately 3,000 steps per day, with each additional 1,000 steps per day significantly reducing the risk of death from various causes. It is worth noting that the recommended daily step count varies by age; however, there are no official guidelines specifying the recommended number of steps per day for different age groups.

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Informed Consent Statement: the manuscript is a survey of accessible specialist literature and it did not require conducting any physical examinations in its participants.

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