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*The Journal welcomes articles on different aspects of physical education, sports and health of students which cover scientific researches in the related fields, such as biomechanics, kinesiology, medicine, psychology, sociology, technologies of sports equipment, research in training, selection, physical efficiency, as well as health preservation and other interdisciplinary perspectives.*

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**PES**  
PHYSICAL  
EDUCATION  
OF STUDENTS

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PHYSICAL  
EDUCATION  
OF STUDENTS

ISSN 2308-7250

2024  
05



**Key title:** Physical Education of Students

Frequency - 6 numbers in a year.

**Abbreviated key title:** Phys. educ. stud.

ISSN 2308-7250 (English ed. online)

<http://www.sportedu.org.ua>

**Publisher:** IP Iermakov S.S. (Ukraine); (Doctor of Sciences in Pedagogy, professor).

Journal is ratified Ministry of Education

Certificate to registration: KB 21884-11784P  
21.12.2015.

and Science of Ukraine (online):

**Address of editorial office:**

Polyova Street, Building 8, Apartment 111,  
Kharkiv, 61068, Ukraine.

physical education and sport: (11.07.2019, №  
975, "A" - 24.00.01, 24.00.02, 24.00.03; 017);  
(13.03.2017, № 374).

e-mail: [sportart@gmail.com](mailto:sportart@gmail.com)

pedagogical sciences: (07.05.2019, № 612, "A" -  
13.00.02; 011, 014); (22.12.2016, № 1604).

#### Indexing:

##### Web of Science Core Collection

[Emerging Sources Citation Index (ESCI)]  
<https://mjl.clarivate.com/home>

##### Open Ukrainian Citation Index (OUCI)

<https://ouci.dntb.gov.ua/en/editions/3lDkV60E/>

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<http://www.doaj.org>

MIAR - <http://miar.ub.edu/issn/2308-7250>

ERIH PLUS (The European Reference Index for  
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## Effects of small-sided games on some recovery markers in football

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

### Abstract

**Background and Study Aim** Small-sided games (SSGs) are widely used in football training to replicate match conditions while controlling the physical load on players. Variations in the number of players during these games can significantly influence key recovery markers. This study aims to investigate the effects of variations in player numbers on maximal heart rate, blood lactate levels, and perceived exertion in small-sided games acutely applied in football.

**Material and Methods** The study involved 28 male football players who were also university students (mean age 24.89±4.59 years, mean height 179±0.04 cm, mean body weight 73.21±4.34 kg). The participants were divided into three groups based on the number of players (2 vs. 2, 4 vs. 4, and 8 vs. 8). Heart rate and lactate levels were measured at three time points: before training, immediately after training, and 30 minutes post-training.

**Results** The study revealed that post-training maximal heart rates (MHR) and lactate levels were significantly higher across all groups compared to pre-training levels, while measurements taken 30 minutes post-training were significantly lower than post-training levels ( $P<0.05$ ). No significant differences were found between pre-training and 30-minute post-training MHR values across the three groups ( $P>0.05$ ). Post-training MHR values were similar between the 2 vs. 2 and 4 vs. 4 groups ( $P>0.05$ ), whereas the 8 vs. 8 group showed significantly higher values ( $P<0.05$ ). Post-training and 30-minute post-training lactate levels were similar between the 4 vs. 4 and 8 vs. 8 groups ( $P>0.05$ ), but the 2 vs. 2 group had significantly lower levels ( $P<0.05$ ). Perceived exertion levels post-training were similar between the 2 vs. 2 and 4 vs. 4 groups ( $P>0.05$ ), while the 8 vs. 8 group reported significantly higher perceived exertion levels ( $P<0.05$ ).

**Conclusions** Small-sided games with varying numbers of players are an effective method for modulating physical load during football training. These findings underscore the importance of considering game format in designing training sessions to optimize player performance and recovery.

**Keywords:** small-sided games, football training, maximal heart rate, blood lactate, perceived exertion.

### Introduction

In football, training methods are continuously evolving to optimize player performance and recovery. Small-sided games (SSGs) have gained widespread popularity due to their ability to replicate match conditions while allowing for controlled physical load. However, the variation in the number of players in these games introduces significant challenges in understanding their impact on key physiological markers. Despite their frequent use, there is a clear need for more effective solutions to address this issue.

In this context, the most important parameters for measuring performance in football encompass physical, physiological, technical, and tactical characteristics [1]. In contemporary football, coaches strive to integrate training exercises and organized game formats that enhance players' physical, technical, and tactical capacities simultaneously [2, 3]. Control of training load, manipulation of small-sided games through variables such as repetition

count, duration of each repetition, and rest intervals, along with the use of internal and external load metrics, have been identified as reliable methods for monitoring training stimulus response in football [4]. Given the necessity of training athletes in all requisite conditioning attributes, small-sided games are frequently employed in football training [5].

Small-sided games encompass movements performed during matches, such as passing, ball control under pressure, quick decision-making, directional changes in running, dribbling with the ball, and shooting [6]. A significant element of small-sided games lies in their potential to offer diverse variations to achieve different training objectives. By altering game conditions, such as rules, field size, player numbers, game duration, work-to-rest ratio, or the presence of goalkeepers, exercise intensity can be effectively regulated [7]. While small-sided games have been widely adopted by coaches as an integrated training approach that resembles football-specific skills, certain task constraints (field dimensions, space per player, and player numbers) can encourage physiological and physical stimuli

aligned with football demands [8, 9, 10, 11].

The capacity to replicate high-intensity movements of the same quality within short intervals during a game relies on the replenishment of depleted anaerobic energy sources through the utilization of aerobic energy sources [12]. This is closely associated with the time players spend below the anaerobic threshold [13]. During a football match, the average exercise intensity is reported to be around 80-90% of the anaerobic threshold or maximum heart rate. Increasing exercise intensity leads to the accumulation of lactic acid in the blood and muscles, which contributes to player fatigue and negatively impacts performance. The ability of players to perform repeated movements of the same quality during this period is closely linked to their enhanced endurance capacity [12].

During a football match, professional athletes maintain a running pace close to their anaerobic threshold, at approximately 80-90% of their maximal heart rate, covering a distance of about 10 kilometers. Intensive elements such as short sprints, passing, and jumping are heavily incorporated among the strength components. The aerobic nature of football is linked to its duration, with a footballer's effort throughout the match remaining near their maximum heart rate. In this high-duration sport, the accumulation of lactic acid due to prolonged intense effort makes sustaining performance at the same level exceedingly challenging. To facilitate the removal of lactic acid, athletes require moments of reduced effort during the competition [14].

One of the parameters used to determine the physiological demands of football is heart rate. Heart rate is defined as the total number of heartbeats per minute. Influenced by the sympathetic and parasympathetic nervous systems, heart rate is considered a significant indicator for monitoring circulatory function [15,16]. Heart rate averages obtained during preparation and official football matches have been reported to vary between 157 and 175 beats per minute (bpm) [17,18,19,20]. Generally, in elite or sub-elite footballers, the average heart rate during a match ranges from 170 to 180 bpm, with the maximal heart rate (MHR) reaching approximately 75-80% of MHR [21]. Workload ratios measured with maximal heart rate during match conditions typically reveal a profile close to the anaerobic threshold (around 80-90% of MHRmax or 75% of VO<sub>2</sub>max) [22,23]. Average blood lactate (LA) concentrations during a football match typically range from 6 to 12 mmol/L, though they can exceed 12 mmol/L under specific or individual circumstances [23,24]. However, the average blood lactate level is generally observed to be around 7 mmol/L. It has also been reported that matches are played at a heart rate corresponding to 70% of maximum oxygen consumption, with lactate values ranging from 3 to 9 mmol/L [25].

Training intensity in small-sided games can be determined using tools such as heart rate measurement devices, GPS tracking systems, and blood lactate measurement tools. However, frequent blood lactate measurements during football training are often challenging to obtain. Therefore, heart rate monitors are commonly used as a convenient and reliable tool in scientific studies, training exercises, and matches in football [26, 27, 28, 29, 30, 31].

The concept of a recovery strategy involves the application of techniques or a combination of techniques to accelerate the process of full recovery and potentially reduce the risk of injury [32, 33]. The ability to maintain or achieve high exercise intensity during repetitions of small-sided games depends on effective post-exercise recovery. Coaches should ensure that the duration of small-sided games and the rest intervals between repetitions are appropriately adjusted based on the required physical effort for the exercises [4].

Familiarity with the physiological needs of footballers enhances coaches' ability to plan training, address energy demands, and minimize the risk of injuries [34]. The impact of small-sided games on aerobic or anaerobic demand and recovery strategies remains not fully understood [35]. Additionally, conflicting results exist in studies regarding the effects of variations in player numbers in different areas on recovery during football-specific small-sided games. Therefore, this study aims to investigate the effects of variations in player numbers on maximal heart rate, blood lactate levels, and perceived exertion in small-sided games acutely applied in football.

## Materials and Methods

### *Participants*

The study included 28 male football players who were also university students (mean age 24.89±4.59 years, mean height 179±0.04 cm, mean body weight 73.21±4.34 kg) actively engaged in football for an amateur league team (Table 1). Prior to the study, participants were informed about the research and asked to sign a voluntary consent form.

### *Research Design. Anthropometric Measurements*

Height measurements of the players were taken using a wall-mounted stadiometer (Holtain, UK) with a precision of 0.1 cm. Body weight measurements were conducted using an electronic scale (Tanita TBF401A, UK) with a precision of 0.1 kg. Additionally, body fat percentage (%) was measured using the bioelectrical impedance analysis (BIA) method (Tanita TBF401A, UK).

### *Warm-up Protocol*

Before beginning the training, the football players participated in a 20-minute active warm-up session tailored to the specific movements they would perform during the session.

**Table 1.** Perceived Exertion Level According to the Borg Scale [38].

| Score | Degree of Exertion |
|-------|--------------------|
| 6     |                    |
| 7     | Very, very light   |
| 8     |                    |
| 9     |                    |
| 10    | Very light         |
| 11    |                    |
| 12    | Fairly light       |
| 13    |                    |
| 14    | Somewhat hard      |
| 15    |                    |
| 16    | Hard               |
| 17    |                    |
| 18    | Very hard          |
| 19    |                    |
| 20    | Very very hard     |

#### *Maximal Heart Rate (MHR) Measurements*

Heart rate measurements during the small-sided games were conducted using a heart rate monitor (Polar Team Pro 2, Polar Electro, Finland) capable of measuring at 1-second intervals. Maximal heart rates of the players were measured at three time points: before, immediately after, and 30 minutes after the small-sided game sessions, and the data were recorded.

#### *Lactic Acid (La) Measurements*

Following the training, the half-life of lactate in the blood ranges from 15 to 25 minutes. The return of blood lactate levels to pre-training levels occurs within 30 to 60 minutes [36, 37]. Based on this literature, blood lactate levels of the football players were measured at three time points—before, immediately after, and 30 minutes after a 3-set session of small-sided games conducted within a one-day training period. Blood lactate concentrations were measured using a lactic acid analyzer (Lactate Scout, Germany) capable of providing results within 10 seconds. Prior to all measurements, the analyzer was calibrated using control solutions with known low (1-1.6 mmol/L LA) and high (4-5.4 mmol/L LA) concentrations, according to the manufacturer’s instructions. Blood lactate concentration was measured from capillary blood obtained from the fingertip. A lancet (Vital Plus, China) and lancet device (Vital Plus, China) were used to collect blood samples. The samples were analyzed within 10 seconds, and the values obtained were recorded in mmol/L units.

#### *Perceived Exertion Level (PEL) Measurements*

Perceived exertion levels of the football players were measured using the 6-20 Borg Scale. At the end

of the study, the players were presented with the Borg Scale and asked to indicate how challenging they perceived the small-sided game to be. On the Borg Scale, 6 (No Fatigue at All) represents the lowest level of exertion, while 20 (Maximal Fatigue) represents the highest level (Table 2).

#### *Small-Sided Games (SSGs)*

When designing SSGs, the length and width of the field can be adjusted based on the desired training stimulus for football players, allowing for pre-planned and adjustable field dimensions [3, 39, 40]. In this study, field dimensions were measured in meters and marked with training cones. Standard-sized footballs (Nike, USA) were used during the SSGs. To objectively group the players, the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) was conducted, and groups were formed based on the distance covered. The football players were divided into three groups: 2 vs. 2, 4 vs. 4, and 8 vs. 8 SSG groups. Each group participated in a one-day acute training program that included three sets of SSGs.

*1. 2 vs. 2 Small-Sided Game Group:* In this group, 2 vs. 2 SSGs were played on a 20x25 meter field, with each set lasting 4 minutes, for a total of 3 sets. A 3-minute passive rest was provided between sets. The total playing area was 300 m<sup>2</sup>, with 75 m<sup>2</sup> per player.

*2. 4 vs. 4 Small-Sided Game Group:* In this group, 4 vs. 4 SSGs were conducted on a 30x35 meter field, with each set lasting 4 minutes, for a total of 3 sets. A 3-minute passive rest was provided between sets. The total playing area was 750 m<sup>2</sup>, with 94 m<sup>2</sup> per player.

*3. 8 vs. 8 Small-Sided Game Group:* In this group, 8 vs. 8 SSGs were conducted on a 40x45 meter field, with each set lasting 4 minutes, for a total of 3 sets. A 3-minute passive rest was provided between sets. The total playing area was 3000 m<sup>2</sup>, with 188 m<sup>2</sup> per player. During the execution of the SSGs, assistant coaches immediately returned balls that went out of play back into the game. Players were encouraged by coaches throughout the game. Following the sessions, players engaged in 20 minutes of jogging and stretching exercises.

The statistical analysis was conducted using the SPSS for Windows 26.0 software package. The arithmetic means and standard deviations of all parameters were calculated. To assess the normality of the data, the Shapiro-Wilk test was performed, revealing that the data did not follow a normal distribution. To detect intergroup differences, the Kruskal-Wallis H test was employed, and the Mann-Whitney U test was used to identify the source of these differences. Within-group measurements at different time points were analyzed using the Repeated Measures Analysis of Variance test. Differences were considered significant at a level of  $p < 0.05$ .

## Results

When the intra-group maximal heart rate and lactate levels of the participants were examined, it was observed that the post-training heart rate and lactate levels in all groups were significantly higher than the pre-training values, and the measurements taken 30 minutes after training were consistently lower than the post-training levels ( $P < 0.05$ ). Additionally, in all groups, the values obtained 30 minutes after training were significantly higher than the pre-training values ( $P < 0.05$ ) (Table 3).

When the inter-group maximal heart rates of

the football players were examined, it was found that the pre-training and 30-minute post-training heart rates were not significantly different among the three groups ( $P > 0.05$ ). After the training, while the heart rates of the 2 vs. 2 and 4 vs. 4 groups were similar ( $P > 0.05$ ), they were significantly higher in the 8 vs. 8 group ( $P < 0.05$ ) (Table 4).

Upon analyzing the inter-group lactate levels of the football players, it was found that the pre-training levels were not significantly different among the three groups ( $P > 0.05$ ). The post-training and 30-minute post-training lactate levels of the 4 vs. 4 and 8 vs. 8 groups were similar ( $P > 0.05$ ),

**Table 2.** Physical Characteristics of the Participants

| Physical Characteristics | N  | Mean  | Standard Deviation | Range | Minimum | Maximum |
|--------------------------|----|-------|--------------------|-------|---------|---------|
| Age, years               | 28 | 24.89 | 4.597              | 15    | 17      | 32      |
| Height, cm               | 28 | 1.79  | .047               | .18   | 1.70    | 1.88    |
| Body weight, kg          | 28 | 73.21 | 4.349              | 18    | 65      | 83      |
| BMI, kg/m <sup>2</sup>   | 28 | 22.76 | 1.241              | 4.00  | 20.65   | 24.66   |

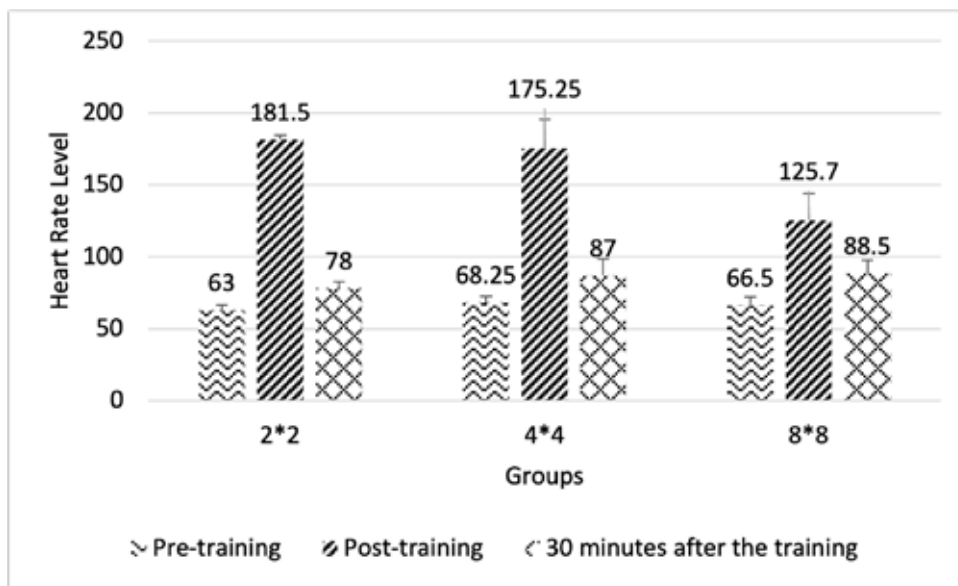
**Table 3.** Intra-group comparisons of the maximal heart rate and lactate levels of the participants

| Game Formats | Parameters         | Pre-training (1) | Post-training (2) | 30 minutes after the training (3) | P     | Intra-group difference |
|--------------|--------------------|------------------|-------------------|-----------------------------------|-------|------------------------|
| 2 vs. 2      | Maximal heart rate | 63.0±3.46        | 181.5±3.00        | 78.0±4.89                         | 0.001 | 1<2                    |
|              |                    |                  |                   |                                   |       | 1<3                    |
|              |                    |                  |                   |                                   |       | 2>3                    |
| 4 vs. 4      | Lactate            | 1.35±0.26        | 11.65±2.73        | 3.1±1.03                          | 0.001 | 1<2                    |
|              |                    |                  |                   |                                   |       | 1<3                    |
|              |                    |                  |                   |                                   |       | 2>3                    |
| 8 vs. 8      | Maximal heart rate | 68.25±4.46       | 175.25±20.05      | 87.0±11.56                        | 0.001 | 1<2                    |
|              |                    |                  |                   |                                   |       | 1<3                    |
|              |                    |                  |                   |                                   |       | 2>3                    |
| 8 vs. 8      | Lactate            | 1.47±0.27        | 7.72±1.89         | 2.38±0.49                         | 0.001 | 1<2                    |
|              |                    |                  |                   |                                   |       | 1<3                    |
|              |                    |                  |                   |                                   |       | 2>3                    |
| 8 vs. 8      | Maximal heart rate | 66.5±5.77        | 125.7±18.41       | 88.5±9.33                         | 0.001 | 1<2                    |
|              |                    |                  |                   |                                   |       | 1<3                    |
|              |                    |                  |                   |                                   |       | 2>3                    |
| 8 vs. 8      | Lactate            | 1.44±0.25        | 6.22±2.38         | 2.09±0.50                         | 0.001 | 1<2                    |
|              |                    |                  |                   |                                   |       | 1<3                    |
|              |                    |                  |                   |                                   |       | 2>3                    |

$P < 0.05$ . 1: Pre-training, 2: Post-training, 3: 30 minutes after the training

**Table 4.** The inter-group comparisons of maximal heart rate, lactate levels, and perceived exertion levels of the participants

| Parameters                            | Time                          | 2*2        | 4*4          | 8*8         | p     | Inter-group differences |
|---------------------------------------|-------------------------------|------------|--------------|-------------|-------|-------------------------|
| Maximal heart rate                    | Pre-training                  | 63.0±3.46  | 68.25±4.46   | 66.5±5.77   | 0.275 | -                       |
|                                       | Post-training                 | 181.5±3.00 | 175.25±20.05 | 125.7±18.41 | 0.001 | 2>8<br>4>8              |
|                                       | 30 minutes after the training | 78.0±4.89  | 87.0±11.56   | 88.5±9.33   | 0.168 | -                       |
| Lactate                               | Pre-training                  | 1.35±0.26  | 1.47±0.27    | 1.44±0.25   | 0.735 | -                       |
|                                       | Post-training                 | 11.65±2.73 | 7.72±1.89    | 6.22±2.38   | 0.001 | 2>4<br>2>8              |
|                                       | 30 minutes after the training | 3.1±1.03   | 2.38±0.49    | 2.09±0.50   | 0.018 | 2>8                     |
| Perceived exertion level (Borg Scale) |                               | 17.0±0.81  | 16.0±0.53    | 14.56±0.96  | 0.001 | 2>8<br>4>8              |



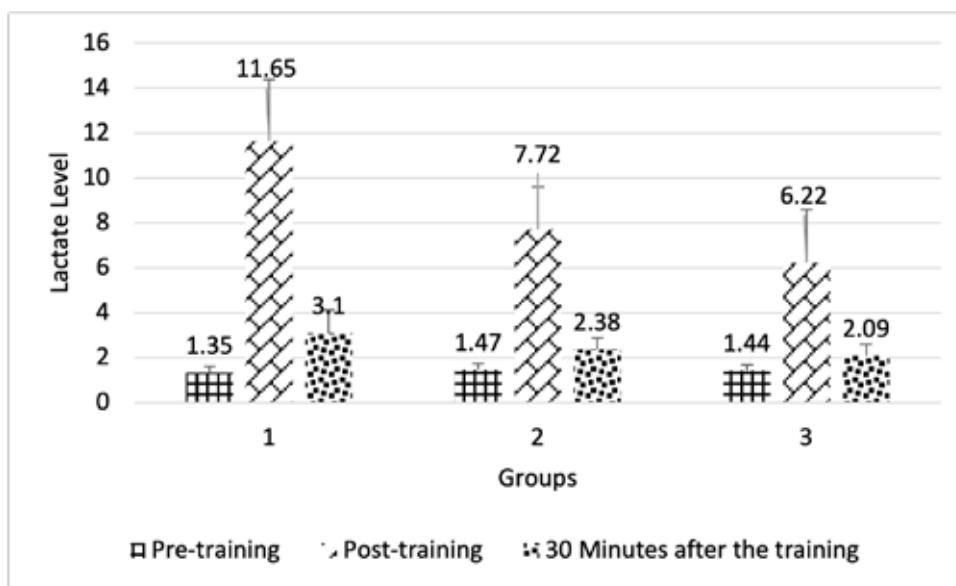
**Figure 1.** Group Comparisons of Maximal Heart Rates

while they were significantly lower in the 2 vs. 2 group ( $P<0.05$ ). In the study, after the training, the perceived exertion levels of the 2 vs. 2 and 4 vs. 4 groups were similar ( $P>0.05$ ), whereas they were significantly higher in the 8 vs. 8 group ( $P<0.05$ ).

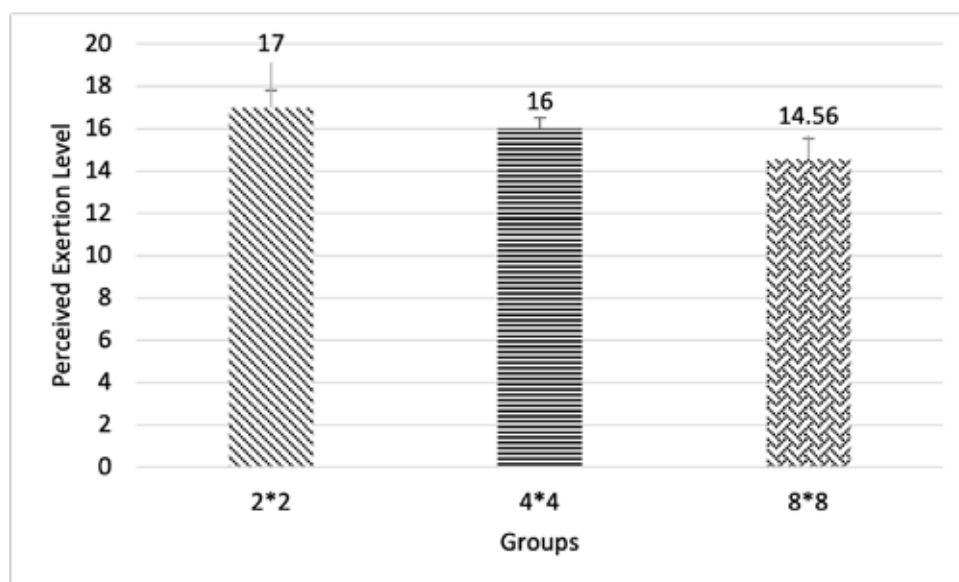
Immediately after the training, the highest average heart rate was observed in the 2 vs. 2 group (181.5 bpm), while the 4 vs. 4 group reached a close average (175.25 bpm). In contrast, the 8 vs. 8 group exhibited a significantly lower average heart rate (125.7 bpm). Measurements taken 30 minutes post-training to assess recovery showed that the 2 vs. 2 group had the lowest average heart rate (78 bpm), the 4 vs. 4 group had a slightly higher average (87 bpm), and the 8 vs. 8 group maintained levels at

around 88.5 bpm (Figure 1).

Upon examining the lactate level findings, it was observed that athletes in the first group (2 vs. 2) reached a peak of 11.65 mmol/L and then decreased to 3.1 mmol/L during the recovery period 30 minutes after training. In the second group (4 vs. 4), lactate levels were noted at 7.72 mmol/L, which decreased to 2.38 mmol/L at the end of the 30-minute recovery period. For the third group (8 vs. 8), lactate levels reduced from an initial 6.22 mmol/L to 2.09 mmol/L during the recovery phase (Figure 2). When asked about the perceived exertion level of the training session, athletes in the 2 vs. 2 group rated the intensity with an average score of 17. In comparison, participants in the 4 vs. 4 group gave an average



**Figure 2.** Group Comparisons of Lactate Values (group 1: 2 vs. 2, 2: 4 vs. 4 and 3: 8 vs. 8)



**Figure 3.** Inter-Group Comparisons of Perceived Exertion Levels

score of 16, while those in the 8 vs. 8 group reported a lower average difficulty rating of 14.56 (Figure 3).

## Discussion

This study aimed to investigate the effects of variations in the number of players during acute small-sided games in football on maximal heart rates (MHR), blood lactate levels, and perceived exertion (PE) levels. It is suggested that small-sided games can increase athletes' heart rates, which in turn may enhance their endurance [41]. The study revealed that in the 2 vs. 2, 4 vs. 4, and 8 vs. 8 game groups, post-training MHR and lactate levels were significantly higher than pre-training levels, while measurements taken 30 minutes after the training were significantly lower than post-training levels. The notable increase in values 30 minutes after

training across all groups suggests that the football players were subjected to a heavy training load and had not fully recovered. The elevated heart rate after the 30-minute rest period might indicate insufficient endurance training levels among the participating footballers. Additionally, despite no significant intergroup differences in MHR values before and 30 minutes after the training, post-training measurements revealed a higher MHR in the 2 vs. 2 group. This finding aligns with previous research [42], which indicates that players respond with a higher MHR during 3 vs. 3 small-sided games compared to larger (9 vs. 9) small-sided games.

In our study, the high maximal heart rate (MHR) attained due to the reduction in player numbers aligns with previous research conducted with amateur and professional athletes [29, 43].

Furthermore, both the 2 vs. 2 and 4 vs. 4 game groups exhibited the highest intragroup and intergroup MHR values immediately after the training, which is consistent with other studies in the literature (>80% MHRmax) [44, 45, 46]. In a study conducted by Little & Williams [26], involving six different pitch sizes and player numbers (2 vs. 2: 27x18m, 3 vs. 3: 32x23m, 4 vs. 4: 37x27m, 5 vs. 5: 41x27m, 6 vs. 6: 46x27m, and 8 vs. 8: 73x41m) during small-sided games (SSGs) in football, a decrease in maximal heart rate percentage was observed (ranging from 88.9% to 87.9%), which is similar to our findings. Consistent with our study, previous research on small-sided games has demonstrated that a 4-minute training bout induces an intensity close to 90% of maximal heart rate (MHR) and contributes to enhancing players' physical fitness [47].

In our study, the higher perceived exertion levels observed in the 2 vs. 2 small-sided game group compared to the other groups indicate that the 2 vs. 2 game format places players under a greater physical load. Michailidis et al. [48] also showed that, based on GPS data, the average heart rate is higher in smaller areas than in larger ones. These findings highlight substantial differences in perceived exertion and lactate levels among players during small-sided games. Some studies [29, 49] have reported that an increase in individual playing area during small-sided games leads to a simultaneous increase in physical and physiological workloads as well as perceived exertion levels. However, our study and certain other research in the literature do not fully support this trend [50, 51]. The level of exertion can be further understood by examining lactate levels [2]. The study by Rampinini et al. [29], which reported an increase in lactate accumulation in athletes as the number of players decreased, is in line with our findings. Moreover, subsequent studies have also revealed that as the number of players decreases in small-sided games, lactate concentrations increase [52, 53]. In a study conducted on female soccer players, it was observed that the %HRmax responses were significantly lower during 2 vs. 2 small-sided games compared to 3 vs. 3 and 4 vs. 4 games, while La and PE responses showed significant differences [54].

Furthermore, in the study conducted by Köklü et al. [55], long-duration small-sided games were found to result in lower blood lactate levels and perceived exertion levels compared to short-duration and frequently played small-sided games. Boge et al. [56] observed that higher blood lactate levels occurred in small-sided games with fewer players, but this result did not produce a significant difference. They also found that there was no difference in heart rate and perceived exertion levels with an increasing number of players. According to Aguiar et al. [57], the decrease in perceived exertion and lactate levels with increasing player numbers could be

attributed to reduced interaction with teammates and opponents. Moreover, technical actions such as ball control can particularly increase perceived exertion and lactate concentrations in games with fewer players [58]. This result is consistent with our study's findings of lower lactate and perceived exertion levels in the 8 vs. 8 game group compared to the other groups. A study with two different small-sided game models, 3 vs. 3 and 5 vs. 5, found that perceived exertion was higher when the number of players decreased [59]. Beato et al. [60] revealed that the lowest perceived exertion level occurred during 8 vs. 8+2 small-sided games, as a result of small-sided games (10 vs. 10, 9 vs. 9+3, 8 vs. 8+2, 7 vs. 7+3, 6 vs. 6, and 6 vs. 4) applied to different numbers of soccer players.

Our study revealed that as the number of players decreased in the other groups compared to the 8 vs. 8 game group, lactate levels increased. Another study conducted with football players found that both a decrease in player numbers and a reduction in the playing area led to a return of high perceived exertion levels to normal levels [61]. Christopher et al. [62] investigated physical and technical skills by manipulating rest-exercise intervals between small-sided games in elite young football players. They found that the total duration of the game determined the exercise intensity in small-sided games. In our study, despite the 2 vs. 2 game group having the same duration as the other groups (4 minutes), it reached the highest lactate levels and perceived exertion levels. This result is significant as the 2 vs. 2 small-sided game involves fewer players and takes place in a smaller area compared to the other groups, indicating that players are exposed to more tackles and changes of pace. Therefore, the 2 vs. 2 game group places players under more locomotor and internal load compared to the 4 vs. 4 and 8 vs. 8 game groups.

Similarly, [53] reported higher lactate and perceived exertion levels in the 2 vs. 2 group compared to the other groups after applying 2 vs. 2, 3 vs. 3, and 4 vs. 4 small-sided games. [26] investigated the effect of different field sizes and player numbers (2 vs. 2: 27x18m, 3 vs. 3: 32x23m, 4 vs. 4: 37x27m, 5 vs. 5: 41x27m, 6 vs. 6: 46x27m, and 8 vs. 8: 73x41m) on football players' lactate and perceived exertion levels and found results (lactate: 9.6 mmol - 8.5 mmol - 9.5 mmol - 7.9 mmol - 5.6 mmol - 5.8 mmol) similar to our study. Changes in the number of players generally affect training intensity in small-sided games. Hill-Haas et al. [30] reported that time-motion characteristics (total distance covered) and acute perceptual responses were affected, but physiological responses were not. The perceived exertion levels of 3-player teams were higher than those of 4-player teams. This finding is consistent with other studies [63, 64] which reported an increase in perceived exertion levels with a

decrease in the number of players when field size remains constant. Similarly, studies have shown that with an increase in field sizes and the number of players (2 vs. 2: 27x18m, 3 vs. 3: 32x23m, 4 vs. 4: 37x27m, 5 vs. 5: 41x27m, 6 vs. 6: 46x27m), perceived exertion levels decrease (16.3 - 15.7 - 15.3 - 14.3 - 13.6, respectively) [15].

This study demonstrates that the number of players in small-sided games significantly influences physiological and perceptual responses in football players. Smaller game formats, such as 2 vs. 2, place a greater physical load on players, leading to higher lactate concentrations and perceived exertion levels compared to larger formats like 8 vs. 8. These findings highlight the importance of carefully considering player numbers and field size when designing training sessions to achieve specific conditioning goals. Future research should explore

the long-term effects of different small-sided game formats on player performance and recovery, as well as investigate potential strategies to optimize training outcomes across various levels of play.

## Conclusions

Small-sided games in football, particularly those played in limited space with fewer players, have a profound impact on the physiological and perceptual demands placed on athletes. These game formats can be strategically utilized in training to target specific performance outcomes, depending on the desired balance between aerobic and anaerobic conditioning. Understanding the relationship between game structure and training load is crucial for optimizing player development and ensuring effective recovery management.

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Cite this article as:

Karadağ T, Patlar S, Bayrak A. Effects of small-sided games on some recovery markers in football. *Physical Education of Students*, 2024;28(5):250–260.

<https://doi.org/10.15561/20755279.2024.0501>

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Received: 01.08.2024

Accepted: 02.09.2024; Published: 30.10.2024

# Comparison of static and dynamic balance performances of sports science students by gender

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## Abstract

**Background and Study Aim** Static and dynamic balance performance are fundamental skills that can exhibit significant differences between genders and are critically important in motor skills and sports science. The aim of this study was to compare the static and dynamic balance performance of sports science students by gender.

**Material and Methods** Ten male students (age:  $22.70 \pm 1.33$  years) and ten female students (age:  $23.00 \pm 1.05$  years) studying in the sports science faculty voluntarily participated in the study. The Biodex Balance System (BBS, Biodex Medical Systems Inc., Shirley, NY) was utilized to assess balance performance. Independent samples t-test and paired t-test were conducted for analysis using SPSS.

**Results** In intergroup comparisons, static and dynamic balance performances were similar between genders, with a significant difference found only in the S-APSI parameter ( $p = 0.021$ ). Among male participants, a significant difference was observed in the S-MLSI parameter ( $p = 0.015$ ), while no significant differences were found in the other parameters. For female participants, dynamic balance performance significantly outperformed static performance (OSI  $p = 0.018$ , APSI  $p = 0.035$ , MLSI  $p = 0.046$ ). Apart from anterior-posterior balance outcomes, no significant differences were observed between males and females in the other parameters. It was also evident that female participants exhibited significantly superior dynamic balance performance compared to static performance.

**Conclusions** Understanding gender differences in balance performance is crucial for creating effective training programs in sports education. By recognizing these differences, trainers can develop strategies that better meet the specific needs of male and female athletes. This approach can help enhance overall athletic performance.

**Keywords:** balance, gender, static, dynamic.

## Introduction

In sports science, balance performance, both static and dynamic, is a critical component of motor skills. Despite its importance, there is a gap in understanding how these balance performances differ between genders. Such differences, if significant, could have implications for how training programs are designed and implemented in sports education.

In this context, balance in sports performance depends on the development of various fitness components, including balance itself [1]. Balance is achieved by keeping the body's center of gravity aligned vertically with its base of support. This process relies on rapid and ongoing feedback from the visual, vestibular, and somatosensory systems, enabling smooth and coordinated neuromuscular movements [2], which is also referred to as postural control [3]. While the connection between balance ability and the risk of sports injuries is well-

documented [4], the link between balance ability and athletic performance is less clear [5]. In the realm of sports science, understanding gender-specific disparities in balance performance assumes significant importance, as it offers insights into optimizing athletic capabilities and tailoring training strategies to account for specific physiological and biomechanical variations [6, 7].

Gender differences in balance performance have garnered substantial interest due to potential influences stemming from biomechanical and physiological factors [2, 6, 7]. Dynamic balance, essential for tasks involving rapid changes in direction and propulsion, requires real-time adjustments to external forces and proprioceptive feedback [8]. Conversely, static balance, crucial for maintaining stability during static poses and weight-bearing activities, demands meticulous postural control and precise distribution of body weight [9].

The impact of anthropometric variables on body stability presents conflicting findings in specialized research. Some studies have noted weak positive and negative correlations, or even the absence of correlations, between anthropometric measurements

and outcomes in static and dynamic balance tests among female university students, suggesting that no single anthropometric measure can fully explain variations in balance [8]. In contrast, another study found strong correlations between static balance scores and trunk muscle endurance levels among male university students in Tehran [10]. Despite the influence of lower limb muscle strength on body balance, research indicates that toe flexor strength may not significantly affect static standing posture [11]. Patlar and Yilmaz [12] found a correlation between body weight and balance performance. Football training has a clear positive impact on the postural stability and balance of young females. Compared to sedentary females, female participants demonstrate improved utilization of the vestibular system and better asymmetrical distribution of body weight [13]. Examining the balance performances of men and women with diverse anthropometric characteristics, strength, and body weight levels is considered crucial in this context.

Several neurophysiological and mechanical factors significantly impact balance. These factors include characteristics such as an individual's height, weight, body composition, and base of support. Additionally, the distance of the center of mass from the ground, the length and weight of each limb, muscle torque arm length, and the distribution of mass across different body points also play crucial roles [14]. Despite the importance of these factors, the field of balance research remains underexplored, particularly concerning healthy, young, physically active women. Specifically, there is a scarcity of studies directly focusing on the balance of female students [15].

Despite numerous studies investigating balance performance, the influence of gender-specific factors on static and dynamic balance remains inadequately addressed. This is especially true in the context of young, physically active populations. In this context, there is a clear need for more effective solutions to address this problem. The aim of this study was to compare the static and dynamic balance performance of sports science students by gender.

## Material and Methods

### *Participants*

Ten male sport science faculty students participated in the study. Participants were briefed on the study's goals and any potential risks involved. Each volunteer signed a consent form, and the study protocol received approval from the Ethics Committee of Selçuk University Faculty of Sports Sciences (Protocol number 59/31.05.2024).

### *Research Design. Procedure*

Participants were asked to undergo the test three times one week prior to the experiment to become

familiar with the experimental equipment. In the study, participants' dynamic and static balance performances were examined in the dominant leg. Participants were advised to abstain from heavy exercise for 48 hours leading up to the experiment. On the day of the experiment, participants arrived at the laboratory at 10:00 AM and underwent a standard warm-up. Immediately afterward, their balance performances were measured. The measurements were recorded in a computer environment.

### *Balance Performance Test*

The Biodex Balance System (BBS, Biodex Medical Systems Inc., Shirley, NY) was used to evaluate the subjects' dynamic balance (with eyes open) and static balance (with eyes closed). Each participant completed two practice trials to become accustomed to the testing equipment. Subsequently, the balance test was performed on the dominant leg. Participants were asked to balance on one foot with their hands crossed on their shoulders while standing on the BBS's mobile platform. The difficulty setting was adjusted to "Level 5" for the eyes-open condition and set to a static level for the eyes-closed condition. The non-dominant leg was held off the ground, and participants were instructed not to look at the BBS monitor. After the test automatically concluded, three balance scores were recorded: Overall Stability Index (OSI), Anterior-Posterior Stability Index (APSI), and Medial-Lateral Stability Index (MLSI). Lower scores represented better balance performance [16].

### *Statistical Analysis*

The Shapiro-Wilk test was used to assess normality. For datasets not normally distributed, skewness and kurtosis values were also evaluated, with values within the  $\pm 2$  range considered indicative of a normal distribution. Homogeneity of variances was tested using Levene's test. To compare dynamic and static balance outcomes between male and female participants, an independent samples t-test was performed. For within-group balance performance comparisons, a paired samples t-test was applied. All statistical analyses were conducted using SPSS software, version 24.0 (SPSS Inc., Chicago, IL, USA), with a significance level set at  $< 0.05$ .

## Results

The results of the study are summarized in Tables 1, 2, and 3, which present the descriptive statistics and balance performance comparisons between male and female participants. In Table 1, significant differences were found between males and females in height and body weight, while their ages and BMI did not differ statistically. In Table 2, a significant difference in favor of males was found in the Static APSI parameter. No statistical differences were found in the other parameters. Table 3

**Table 1.** Descriptive of participants

| Parameters               |        | Mean   | Std. Deviation | t     | df | 95% CI |        | P     |
|--------------------------|--------|--------|----------------|-------|----|--------|--------|-------|
|                          |        |        |                |       |    | Lower  | Upper  |       |
| Age (year)               | Male   | 22.70  | 1.33           | -.557 | 18 | -1.431 | .831   | .584  |
|                          | Female | 23.00  | 1.05           |       |    |        |        |       |
| Height (cm)              | Male   | 176.40 | 7.30           | 3.728 | 18 | 4.016  | 14.384 | *.002 |
|                          | Female | 167.20 | 2.74           |       |    |        |        |       |
| Body Weight (kg)         | Male   | 71.90  | 6.88           | 5.184 | 18 | 8.148  | 19.252 | *.000 |
|                          | Female | 58.20  | 4.73           |       |    |        |        |       |
| BMI (kg/m <sup>2</sup> ) | Male   | 22.50  | 2.22           | 2.004 | 18 | -.086  | 3.686  | .060  |
|                          | Female | 20.70  | 1.76           |       |    |        |        |       |

\*: p<0.05.

**Table 2.** Comparison of static and dynamic balance performances by gender

| Parameters           |        | Mean | Std. Deviation | t      | 95% CI |        | P     |
|----------------------|--------|------|----------------|--------|--------|--------|-------|
|                      |        |      |                |        | Lower  | Upper  |       |
| Dynamic-OSI (score)  | Male   | 2.32 | .59            | .906   | -.3036 | .7636  | .377  |
|                      | Female | 2.09 | .54            |        |        |        |       |
| Dynamic-APSI (score) | Male   | 1.70 | .55            | 1.040  | -.2652 | .7852  | .312  |
|                      | Female | 1.44 | .56            |        |        |        |       |
| Dynamic-MLSI (score) | Male   | 1.26 | .43            | .111   | -.3602 | .4002  | .913  |
|                      | Female | 1.24 | .37            |        |        |        |       |
| Static-OSI (score)   | Male   | 2.58 | .43            | -1.530 | -.7594 | .1194  | .143  |
|                      | Female | 2.90 | .50            |        |        |        |       |
| Static-APSI (score)  | Male   | 1.64 | .33            | -2.535 | -.9510 | -.0890 | *.021 |
|                      | Female | 2.16 | .55            |        |        |        |       |
| Static-MLSI (score)  | Male   | 1.65 | .34            | .957   | -.1554 | .4154  | .351  |
|                      | Female | 1.52 | .25            |        |        |        |       |

\*: p<0.05; OSI - Overall Stability Index; APSI - Anterior-Posterior Stability Index; MLSI - Medial-Lateral Stability Index.

**Table 3.** Comparison of static and dynamic balance performances among male participants

| Parameters           | Mean | Std. Deviation | 95% CI |        | t      | P     |
|----------------------|------|----------------|--------|--------|--------|-------|
|                      |      |                | Lower  | Upper  |        |       |
| Dynamic-OSI (score)  | 2.32 | .59            | -.6908 | .1708  | -1.365 | .205  |
| Static-OSI (score)   | 2.58 | .43            |        |        |        |       |
| Dynamic-APSI (score) | 1.70 | .55            | -.3560 | .4760  | .326   | .752  |
| Static-APSI (score)  | 1.64 | .33            |        |        |        |       |
| Dynamic-MLSI (score) | 1.26 | .43            | -.6829 | -.0971 | -3.012 | *.015 |
| Static-MLSI (score)  | 1.65 | .34            |        |        |        |       |

\*: p<0.05; OSI - Overall Stability Index; APSI - Anterior-Posterior Stability Index; MLSI - Medial-Lateral Stability Index.

**Table 4.** Comparison of static and dynamic balance performances among female participants

| Parameters           | Mean | Std. Deviation | 95% CI  |        | t      | P            |
|----------------------|------|----------------|---------|--------|--------|--------------|
|                      |      |                | Lower   | Upper  |        |              |
| Dynamic-OSI (score)  | 2.09 | .54            | -1.4476 | -.1724 | -2.874 | <b>*.018</b> |
| Static-OSI (score)   | 2.90 | .50            |         |        |        |              |
| Dynamic-APSI (score) | 1.44 | .56            | -1.3755 | -.0645 | -2.485 | <b>*.035</b> |
| Static-APSI (score)  | 2.16 | .55            |         |        |        |              |
| Dynamic-MLSI (score) | 1.24 | .37            | -.5535  | -.0065 | -2.316 | <b>*.046</b> |
| Static-MLSI (score)  | 1.52 | .25            |         |        |        |              |

\*:  $p < 0.05$ ; OSI - Overall Stability Index; APSI - Anterior-Posterior Stability Index; MLSI - Medial-Lateral Stability Index.

indicates that there was a significant difference in the Static-MLSI parameter for static and dynamic balance performances among male participants. No significant differences were found in the other parameters. When comparing the dynamic and static balance performances of female participants, it was found that dynamic performance was significantly higher than static performance (Table 4).

### Discussion

The aim of this study was to compare the static and dynamic balance performances of male and female sports science students. The results indicated significant gender differences in certain balance parameters, with males showing superior performance in the Static APSI parameter and females demonstrating better dynamic balance compared to static balance. These findings suggest that gender-specific factors may influence balance performance in different ways.

It is well documented that athletic performances required in sports, such as strength, speed, agility, endurance, balance [17], and flexibility, vary according to gender, with physical and physiological differences being very evident [18]. The literature on gender-related differences in athletic performance reveals that male athletes generally outperform female athletes in all maximal anaerobic and aerobic performances due to physical and physiological gender-based differences. From a physiological perspective, men have more red blood cells, larger heart and lung capacity, which provide greater aerobic performance, while greater muscle mass, lower body fat, and higher levels of certain hormones contribute to better anaerobic performances [19]. While these physiological advantages dominate in physical efforts, they may be less influential in performances requiring cognitive skills such as flexibility and dynamic balance [20]. In fact, women's balance ability may even be better than men's in some cases [21, 22]. Although some evidence suggests that these differences may be linked to anthropometric variations [23], Nolan and

Grigorenko [24] argued that gender differences were not dependent on anthropometrics. In light of this literature, it remains a debatable issue whether, and to what extent, gender-related differences in balance ability exist.

Hageman and Leibowitz [25], Wolfson et al. [26], and Fujiwara and Toyama [27] reported non-significant differences between genders. Similarly, Demura and Yamaji [20] measured four stepping tests requiring dynamic balance ability and found no gender-related differences in the number of steps or the average time taken to transition between stepping right and left. However, they observed significant differences between genders in the total connecting time during bilateral stepping (right and left) and in the number of steps during unilateral right/left stepping. This suggests that females might be more adept at maintaining stability during the phase when both feet are on the ground, while males may be more effective at sustaining stability during the leg-raising phase.

Balance can be categorized into various types: static steady-state balance (the ability to maintain a stable position while standing or sitting), dynamic steady-state balance (the ability to remain stable while walking), proactive balance (anticipating and preparing for a predicted postural disturbance), and reactive balance (compensating for an unexpected postural disturbance) [23, 28]. Considering this information alongside the literature mentioned above, it appears that there are no major differences between men and women in terms of dynamic balance skills. However, it is important to note that the sample groups in these studies consist of older individuals compared to the sample group in our study.

While many studies have shown a decrease in balance ability with aging, gender-related differences in dynamic balance may also be age-dependent [20]. For this reason, further studies should consider our findings in relation to theirs.

Schedler and Kiss [23] reported that balance performance develops from early childhood,

with physical factors such as growth and weight gain having only a minimal impact on balance performance in youth. Era et al. [29] found that males exhibited more pronounced sway, as evidenced by the speed and amplitude of center of pressure movements during force platform measurements, with these differences being more pronounced in older age groups. Among children, girls may demonstrate better postural control than boys of the same age [30, 31], which is attributed to enhanced sensory integration, more advanced neuromuscular development, and the use of more mature postural control strategies. Additionally, it has been suggested that girls tend to be less hyperactive and more attentive during balance tasks compared to boys [23].

Studies investigating gender-related dynamic balance differences within the age range of our study sample are very limited. Schedler and Kiss [23] highlighted this issue and emphasized the need for more research on this subject, particularly with well-designed and large cohort studies. Given the limited research in this area, our findings provide valuable insights but should be interpreted with

caution. Another limitation of our study is the relatively small sample size, which may affect the generalizability of the results. Additionally, the cross-sectional design does not allow for observations of balance performance changes over time. Incorporating more advanced biomechanical analysis and exploring other potential influencing factors, such as hormonal fluctuations and training regimens, could further enhance the depth of understanding in this field.

## Conclusions

The study demonstrated a significant superiority of dynamic balance performance over static balance in men, with some elements of balance performance being more successful in women. Our findings also confirmed significant differences between static and dynamic balance when considering the Medio-Lateral Stability Index. Although this finding was not the primary focus of our research, it suggests that further studies exploring the differences between static and dynamic balance could benefit from this information.

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Cite this article as:

Taskuyu E, Atçeken DH, Savga MB, Sacikara A, Atalay R, Gungor H. Comparison of static and dynamic balance performances of sports science students by gender. *Physical Education of Students*, 2024;28(5):261–267. <https://doi.org/10.15561/20755279.2024.0502>

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Received: 30.07.2024

Accepted: 30.08.2024; Published: 30.10.2024

# The role of coach-athlete relationship on motivation and sports engagement

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## Abstract

**Background and Study Aim** The relationship between coach and athlete may significantly influence an athlete's experience in sports. Elements such as closeness, commitment, and complementarity are key aspects of this relationship. The current study aimed to examine the association between motivation and athletes' engagement in sports, as mediated by the coach-athlete relationship.

**Material and Methods** A sample of 408 student-athletes from various universities in Iligan City participated in the study. They completed a set of questionnaires assessing motivation, the coach-athlete relationship, and athlete engagement. The participants were between 18 and 25 years old. The measures used in the study included the Coach-Athlete Relationship Questionnaire (CARTQ), the Sports Motivation Scale (SMS), and the Athletic Engagement Questionnaire (AEQ). Ethical approval was obtained from all participants.

**Results** The results showed that coach-athlete relationships were characterized by closeness, commitment, and complementarity. These relationships significantly mediated the link between intrinsic and extrinsic motivation and athlete engagement in sports. Strong connections between coaches and athletes enhance the positive effect of motivation on engagement. This occurs by fulfilling athletes' psychological needs for autonomy, competence, and relatedness. Conversely, amotivation was negatively associated with engagement through the dimensions of the coach-athlete relationship. Athletes with high levels of amotivation are more likely to disengage. This highlights the need for coaches to foster a supportive environment that reduces negative motivational states.

**Conclusions** The evidence supports the utilization of Self-Determination Theory (SDT) to better understand the importance of relationship factors in enhancing motivation. This approach leads to long-term engagement in sports. These results offer a more comprehensive view of the delicate dynamics of the coach-athlete relationship and its consequences for motivation and athletic engagement in sports.

**Keywords:** engagement, motivation, coach-athlete relationship, intrinsic, extrinsic

## Introduction

Despite the growing interest in enhancing athletic performance, there remains a significant challenge in understanding the factors that sustain long-term motivation and engagement among athletes. The complexity of these psychological factors often leads to inconsistent outcomes in both research and practice. This highlights the need for further exploration of the elements that contribute to sustained athletic commitment. In this context, various research topics have shown that the motivation and engagement of athletes in sports have consistently been a subject of interest for researchers and professionals in the field of sports psychology [1, 2, 3]. While engagement has been construed in a variety of ways, it is generally

understood in the literature as persistent and positive cognitive and emotional experiences in sports, characterized by four interconnected dimensions: vigor, dedication, confidence, and enthusiasm [4, 5]. According to Lonsdale et al. [5], vigor refers to a feeling of being physically, mentally, and emotionally lively, defined by high levels of energy and resilience. Dedication, on the other hand, is a strong sensation of being deeply involved in one's sport, along with a sense of facing substantial challenges. Confidence is understood as having trust in one's ability to reach a high level of performance and accomplish desired goals. Enthusiasm embodies a strong sense of excitement and enjoyment. Exploring the factors that influence athlete engagement and understanding how it is formed presents a substantial opportunity to discover the hidden potential and strengths of student-athletes.

Athlete engagement is characterized by pleasant thoughts and feelings that lead to a sense of profound involvement in sports [4, 6, 7]. It includes feelings of excitement, encouragement, and satisfaction about the task [8, 9], as well as deep focus and concentration on sports activities [4, 10]. Research has indicated that athlete engagement is a condition of optimal performance, positively correlated with high levels of achievement in sports [7, 10]. It is also linked to persistence, such as higher flow [11], self-regulation in elite athletes [12], athletes' well-being [13], and lower burnout in student-athletes [14]. The profound impact of engagement in sports on student-athletes, along with the growing acknowledgment that it can be nurtured and improved, has led to increasing interest in understanding the mechanisms that contribute to its development in sports.

However, while several studies have explored the dynamics of improving sports engagement [2, 6, 7, 15], to the author's knowledge, very few have examined these dynamics from the perspective of Self-Determination Theory (SDT). Utilizing this theory [16, 17], this study contends that athletes' motivation tends to enhance coach-athlete relationships (i.e., closeness, commitment, complementarity) and, ultimately, increase athletes' engagement in sports.

The SDT suggests that the quality of an individual's motivation impacts their psychological outcomes [17]. This theory posits that individuals possess three basic psychological needs: the need for autonomy, the need for competence, and the need for relatedness. When these needs are met, individuals tend to be intrinsically motivated, leading them to stay engaged and persistent in their sports activities. In a sports context, athletes who feel in control of their training and performance (autonomy), who can handle challenging situations (competence), and who feel close to their coaches and teammates (relatedness) are more likely to be engaged in their sport. The fulfillment of these basic psychological needs has been positively associated with employee engagement [10, 17, 18], well-being [4, 19], and motivational climate [2], and is therefore believed to be a probable motivational factor for athletes' engagement. According to Ryan and Deci [20], the level of satisfaction of these needs determines the level of positive psychological outcomes, such as engagement. Conversely, frustration or obstruction of these needs determines the level of negative psychological consequences, such as burnout. Furthermore, there is a positive association between a desire for enjoyment and an increased likelihood of engagement in sports. SDT asserts that the coach's motivational climate impacts athletes' levels of intrinsic motivation and engagement in sports [20, 21].

Self-determination theory postulates that the motivational environment created by coaches is

connected to athletes' motivation by fulfilling their basic psychological needs [22, 23]. The type of motivation individuals experience is believed to influence athletes' affective states. A study by Curran et al. [24] claims that the motivational climate plays an important role in the overall quality of engagement in sports, particularly regarding factors such as enthusiasm, vigor, dedication, and confidence. Consequently, athletes' psychological health, well-being, and engagement are more positively affected when their motivation for sport is self-determined [19]. Self-determination theory (SDT) posits that social conditions in an environment impact both the motivational regulations that influence behavior and the psychological experiences, such as athletes' burnout and engagement [6, 1]. Ultimately, athletes' style of motivation is thought to be important to their emotional states and their level of engagement in sports [7, 25, 26]. Various analyses have been conducted on the relationship between the environment provided by coaches and the basic psychological needs of athletes on competitive teams [27, 28]. The findings revealed beneficial connections between coaches who promote autonomy and athletes' perception of their basic psychological needs. Hence, the extent to which athletes feel their needs are met—through their perceptions of autonomy, competence, and relatedness—is influenced by the sports environment established by coaches or significant individuals around the athletes [23, 29]. Thus, self-determination theory aims to understand the motivations behind sports participation and their impact on engagement [30, 31].

The CAR 3C's model, proposed by Jowett and Ntoumanis [32], is the first and most widely used model for understanding coach-athlete relationships [33]. The authors suggest that the attributes within this model are believed to derive from emotion, cognition, and behavior [34, 35, 36]. These characteristics include closeness, which represents the emotional connection between athletes and coaches, encompassing confidence, likability, and trust. Commitment refers to the intention of both athletes and coaches to sustain their relationship and maximize its benefits. Complementarity describes the interaction between athletes and coaches, highlighting how a friendly and responsive attitude from an athlete can lead to a similar response from a coach [32, 37]. Heightened perceptions of these constructs indicate a more positive perception of the coach-athlete relationship.

The 3C's model and its associated measures have been used for two decades to investigate factors related to the coach-athlete relationship [32, 38]. Research has shown that the coach-athlete relationship is associated with various factors such as motivation and needs satisfaction [25, 38],

physical self-concept [39], support and conflict [40, 41], collective efficacy [35], communication [42], and satisfaction and well-being [43, 44, 45]. However, the impact of the coach-athlete relationship on athlete engagement has not been thoroughly investigated. According to Self-Determination Theory (SDT) [22, 23], it is reasonable to argue that a strong and positive relationship between athlete and coach can greatly enhance athlete engagement by fulfilling their basic psychological needs for autonomy, competence, and relatedness. Athletes require a sense of psychological autonomy and choice while participating in sports. They also need to feel competent in handling the environment and achieving desired outcomes. Additionally, athletes seek a sense of warmth, connection, and bonding with their coach and teammates, known as the need for relatedness [20, 23]. Thus, a coach who creates an environment that addresses these basic psychological needs not only enhances the interest of the athlete but also contributes positively to their development [41]. By employing autonomy-supportive coaching interventions, providing constructive feedback, and fostering the athletes' sense of relatedness, a coach can enhance the athlete's psychological needs and ultimately cultivate a thriving, motivated, and resilient athlete [33, 46]. A strong and positive relationship, anchored in SDT, can lead to long-term athlete engagement and the fulfillment of their needs.

Although research has identified several factors that affect athletes' engagement, there is a lack of clarity and theoretical understanding regarding the specific mechanisms that contribute to the development and enhancement of athlete engagement. This study utilizes Self-Determination Theory (SDT) to demonstrate that fulfilling basic psychological needs is crucial for athletes to enhance their engagement in sports. Additionally, this study asserts that coach-athlete relationships mediate the relationship between sports motivation and engagement.

## Materials and Methods

### *Participants*

A total of 408 student-athletes from various universities in Northern Mindanao, Philippines, participated in the study. The participants ranged in age from 18 to 27 years ( $M = 20$  years,  $SD = 1.55$ ). The sample included 247 male athletes (60.5%) and 161 female athletes (39.5%). Using snowball sampling, participants were recruited based on the following criteria: (1) at least 3 years of participation in different tournaments and (2) participation in regional or national competitions in sports.

### *Research Design*

The study employed an inferential approach, utilizing standardized questionnaires to gather data.

The coach-athlete relationship was assessed using the CART-Q [32, 47]. The CART-Q is composed of 11 items, and participants rated each item on a seven-point Likert scale, ranging from (1) strongly disagree to (7) strongly agree. High scores indicate a greater level of connection between coach and athlete. The psychometric properties of this measure are well-established, with Cronbach's alpha scores ranging from 0.70 to 0.88 [38, 35, 48]. The Cronbach's alpha for closeness, commitment, and complementarity are 0.95, 0.95, and 0.96, respectively. The overall internal consistency of the CART-Q is 0.98.

Sports motivation of athletes was measured using the Sports Motivation Scale (SMS) [49]. This scale contains 28 items measuring three factors: intrinsic motivation, extrinsic motivation, and amotivation. Participants responded using a 7-point Likert-type scale ranging from (1) "Does not correspond at all" to (7) "Corresponds completely," with higher scores indicating increased motivation in sports. The SMS has shown adequate levels of internal consistency, ranging from 0.73 to 0.86 [50, 51, 52]. In the current study, the SMS demonstrated high internal consistency for intrinsic motivation (0.95), extrinsic motivation (0.96), and amotivation (0.88). The overall Cronbach's alpha of the SMS is 0.98.

The Athletic Engagement Questionnaire (AEQ) [53] was developed to measure sports engagement. This scale comprises 16 items across four dimensions: confidence, dedication, vigor, and enthusiasm. Participants rated each item using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating a higher level of engagement in sports. This scale has demonstrated adequate validity and reliability across multiple investigations [54, 7, 55]. The internal consistency of the AEQ dimensions—confidence, dedication, vigor, and enthusiasm—are 0.95, 0.96, 0.97, and 0.98, respectively. The overall internal consistency of the AEQ is 0.98.

Permission was obtained from the school authorities, and the test administration was carried out following the approval of the university research ethics board. Consent forms were obtained from the participants, clearly outlining the study's objectives and ensuring the anonymity of participants' responses. The participants completed the packet of questionnaires with the assistance of designated researchers. The procedures were subjected to a comprehensive assessment, and the university's ethics review committee authorized the implementation.

### *Statistical Analysis*

All statistical analyses were performed using IBM SPSS Version 20.0 to assess the indirect effects of the coach-athlete relationship on the relationship between motivation and sport engagement of athletes. Before conducting the mediation analysis,

the data were carefully checked, and any missing values were imputed randomly using expectation-maximization (EM) methods. Cronbach's alpha was computed for each scale item to assess internal consistency. Preliminary data analyses were conducted, including the assessment of instrument reliability, frequency, mean, and standard deviation for demographic variables. The PROCESS macro [56] was used to examine the role of the coach-athlete relationship between motivation and engagement of athletes using multiple mediation analysis. A total of 10,000 bootstrap samples were utilized to examine the effects of the parallel mediators. The 95% confidence intervals (CI) for the lower and upper limits that do not include zero indicate significant results at the .05 level.

## Results

The results of the study are presented in Table 1 and Table 2. Table 1 shows the means, standard deviations, and correlations of the study variables. Significant positive correlations were found among intrinsic, extrinsic, and amotivation ( $r = -.13$  to  $.92$ ), confidence, dedication, vigor, and enthusiasm ( $r = -.23$  to  $.96$ ), and coach-athlete relationships characterized by closeness, commitment, and complementarity ( $r = -.23$  to  $.95$ ). It is also significant to note that there was a positive correlation between the dimensions of CAR and intrinsic and extrinsic motivation. Conversely, the results showed a significant negative correlation between amotivation and all dimensions of coach-athlete relationships and athlete engagement.

Table 2 displays the direct, indirect, and total effects among the variables. The study conducted mediation analysis to investigate the indirect effect of the three mediating variables of CAR (i.e., closeness, commitment, and complementarity) on athlete engagement. The results demonstrated that closeness ( $\beta = 0.139$ , 95% CI [.108, .170]), commitment ( $\beta = 0.146$ , 95% CI [.114, .179]), and complementarity

( $\beta = 0.139$ , 95% CI [.107, .171]) had a significant role in mediating the link between motivation and engagement. Furthermore, there was a notable direct impact of motivation on engagement ( $\beta = .017$ ,  $p < .001$ ). Finally, the total effect model was statistically significant ( $\beta = 0.017$ ,  $p < .001$ ). Therefore, athletes who possess high levels of motivation are more likely to engage actively in sports due to the strong bond and positive interaction between coaches and athletes, characterized by these dimensions.

## Discussion

The current study aimed to examine whether motivation influences athletes' engagement in sport through the coach-athlete relationship. The study presents several interesting results that warrant further discussion. The hypothesis proposed that the coach-athlete relationship would mediate the relationship between motivation and athlete engagement. First, the results show that intrinsic motivation is associated with an increase in engagement. This finding suggests that athletes who exhibit intrinsic motivation are more likely to have higher levels of energy, which, in turn, leads to increased effort, the ability to overcome difficulties, and the attainment of desired results. This process is characterized by a sense of purpose, pride, and challenge, ultimately fulfilling a state of personal satisfaction [7, 21, 57].

In Self-Determination Theory (SDT) [16, 58], intrinsic motivation plays a crucial role in increasing athletes' engagement and performance in sports. Research has highlighted that intrinsic motivation enhances athletes' happiness and satisfaction in their sport and boosts performance by fostering toughness, determination, and a deeper dedication to training and competition [59, 60]. This type of motivation is linked to the basic psychological needs of autonomy, competence, and relatedness, which are fundamental to SDT, indicating that athletes are more likely to achieve

**Table 1.** Descriptive statistics and bivariate correlations

|                     | 1      | 2      | 3        | 4      | 5      | 6      | 7      | 8      | 9      | 10    |
|---------------------|--------|--------|----------|--------|--------|--------|--------|--------|--------|-------|
| 1. Intrinsic        | --     |        |          |        |        |        |        |        |        |       |
| 2. Extrinsic        | 0.92** | —      |          |        |        |        |        |        |        |       |
| 3. Amotivation      | -0.13* | -0.15* | —        |        |        |        |        |        |        |       |
| 4. Confidence       | 0.56** | 0.56** | -0.34**  | —      |        |        |        |        |        |       |
| 5. Dedication       | 0.55** | 0.55** | -0.33*** | 0.93** | —      |        |        |        |        |       |
| 6. Vigor            | 0.53** | 0.50** | -0.26**  | 0.86** | 0.88** | —      |        |        |        |       |
| 7. Enthusiasm       | 0.54** | 0.50** | -0.27**  | 0.86** | 0.87** | 0.96** | —      |        |        |       |
| 8. Closeness        | 0.61** | 0.62** | -0.35**  | 0.65** | 0.65** | 0.59** | 0.59** | —      |        |       |
| 9. Commitment       | 0.65** | 0.63** | -0.24**  | 0.59** | 0.59** | 0.60** | 0.61** | 0.87** | —      |       |
| 10. Complementarity | 0.65** | 0.63** | -0.23**  | 0.57** | 0.56** | 0.60** | 0.59** | 0.83** | 0.95** | —     |
| M                   | 48.11  | 70.15  | 13.53    | 17.14  | 17.24  | 17.80  | 18.03  | 17.57  | 24.65  | 24.53 |
| SD                  | 9.61   | 14.83  | 7.90     | 3.70   | 3.83   | 3.61   | 3.58   | 4.07   | 4.74   | 4.78  |

Significant at level \* $p < .01$ , \*\* $p < .001$

**Table 2.** Results of direct, indirect, and total effects

| Path  | Direct Effect<br>$\beta$ (SE) | Indirect Effect<br>$\beta$ (SE)             | Total Effect<br>$\beta$ (SE) |
|---|-------------------------------|---|------------------------------|
| Intrinsic → Closeness → Sports Engagement                   | 0.395 (0.132)**               | 0.187 (0.060)**<br>BC 95% [.069, .304]      | 0.581 (0.141)***             |
| Intrinsic → Commitment → Sports Engagement                  | 0.406 (0.072)***              | 0.424 (0.053)***<br>BC 95% [.320, -.528]    | 0.581 (0.141)***             |
| Intrinsic → Complementarity → Sports Engagement             | 0.342 (0.137)**               | 0.239 (0.058)***<br>BC 95% [.125, .353]     | 0.581 (0.141)***             |
| Extrinsic → Closeness → Sports Engagement                   | 0.231 (0.044)***              | 0.291 (0.033)***<br>BC 95% [.227, .355]     | 0.522 (0.039)***             |
| Extrinsic → Commitment → Sports Engagement                  | 0.248 (0.046)***              | 0.274 (0.033)***<br>BC 95% [.209, -.339]    | 0.522 (0.039)***             |
| Extrinsic → Complementarity → Sports Engagement             | 0.265 (0.046)***              | 0.257 (0.033)***<br>BC 95% [.002, .130]     | 0.522 (0.039)***             |
| Amotivation → Closeness → Sports Engagement                 | - 0.226 (0.069)***            | - 0.200 (0.036)***<br>BC 95% [-.270, -.129] | - 0.425 (0.070)***           |
| Amotivation → Commitment → Sports Engagement                | - 0.306 (0.070)***            | - 0.254 (0.053)***<br>BC 95% [-.357, -.150] | - 0.425 (0.070)***           |
| Amotivation → Complementarity → Sports Engagement           | - 0.333 (0.067)***            | - 0.092 (0.027)***<br>BC 95% [-.145, .321]  | - 0.425 (0.070)***           |
| Motivation → Closeness → Sports Engagement                  | .095 (.021)***                | 0.139 (0.016)***<br>BC 95% [.108, .170]     | 0.234 (0.021)***             |
| Motivation → Commitment → Sports Engagement                 | .088 (.023)***                | .146 (.017)***<br>BC 95% [.114, .179]       | 0.234 (0.021)***             |
| Motivation → Complementarity → Sports Engagement            | .095 (.023)***                | .139 (.017)***<br>BC 95% [.107, .171]       | 0.234 (0.021)***             |
| Motivation → Coach-Athlete Relationship → Sports Engagement | 0.005 (0.002)***              | 0.011 (0.001)***<br>BC 95% [.009 - .014]    | 0.017 (0.001)***             |

Significant at level \* $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

success based on their interests and preferences [20, 23]. Furthermore, fulfilling these basic needs can substantially influence athletes' overall motivation levels and determination to engage in intense training and tournaments. In line with this, an investigation showed that athletes who derive enjoyment and captivation from their actions are more inclined to attain enhanced learning and performance outcomes in various situations [59, 61]. Studies indicate that intrinsic motivation is strongly linked to positive emotional experiences, such as passion, happiness, and a feeling of being challenged [62]. These experiences can result in increased determination, effort, and a greater willingness to take on new challenges. Ultimately,

this can lead to improved performance and engagement in sports.

The second result shows that extrinsic motivation contributes to the increase in athletes' engagement. This suggests that when athletes participate in sports due to external incentives or pressure, it can still result in significant engagement in sports. The current results align with numerous studies indicating that athletes who receive external rewards (e.g., praise or material rewards) are more likely to engage in prolonged training sessions [63, 64], increase their willingness to engage in tasks [1], and experience increased motivation and commitment [2]. This supports Self-Determination Theory (SDT) [16, 58], which posits that while

intrinsic motivation is ideal for sustaining athlete interest and enjoyment, extrinsic motivation can help athletes stay engaged, especially when it aligns with their values and aspirations. For instance, athletes who consistently receive acknowledgment and recognition for their achievements may dedicate more effort to their training routines [65], motivating them to perform at their best [3], ultimately leading to enhanced performance and skills. Although extrinsic motivation enhances engagement in sports, it is important to maintain a balance with intrinsic motivation to avoid potential negative impacts, such as burnout and exhaustion [10, 23, 57]. Consequently, fostering an organizational environment that enhances both intrinsic and extrinsic motivational factors would be beneficial for athletes' well-being as well as their excellence in sports performance.

The third result shows that amotivation is negatively associated with athletes' engagement. These findings indicate that higher levels of amotivation observed in athletes can lead to their withdrawal from sports. This suggests that athletes may exhibit negative attitudes towards their sport, such as reduced effort in practice, lack of interest, and even complete dropout. A study conducted by Kouali et al. [66] suggests that amotivation may serve as a useful indicator for predicting a lack of perseverance in sports and physical activities. Self-Determination Theory (SDT) explains the link between amotivation and athlete engagement [20, 67]. This theory posits that the fulfillment of three basic psychological needs—competence, autonomy, and relatedness—determines individuals' motivation. When these needs are satisfied, athletes develop intrinsic motivation, which is strongly associated with high levels of motivation and performance [61]. Conversely, if these needs are unmet, athletes may experience amotivation, which can subsequently lead to poor performance. Various literature indicates that amotivation is linked to learned helplessness, low need satisfaction, and unfavorable contextual conditions, which may result in non-participation, low engagement, and low intentions to participate in sports and physical activity [66].

Finally, the results show that the roles of the coach-athlete relationship and its dimensions mediate the relationship between sports motivation and athlete engagement. Adhering to the tenets of Self-Determination Theory (SDT), the study examines how the closeness, commitment, and complementarity in the relationship between athletes and their coaches can significantly influence the level of motivation and engagement [22]. In the present study, closeness was found to mediate the relationship between motivation and athlete engagement. Within the context of SDT, the closeness between coaches and athletes fulfills the need for relatedness. This implies that athletes,

through caring and friendly interactions with their coach, cultivate a sense of worth and belonging.

Simons and Bird [34] highlight that when a player forms an emotional connection with a coach, participating in the activity for enjoyment or being motivated by rewards leads to a higher degree of engagement in sports. The formation of a compassionate and supportive relationship partially contributes to athletes feeling accepted, included, and secure, which further helps them to maintain their engagement. The concept of commitment, which acts as a mediator between motivation and athletes' engagement, is associated with the need for autonomy in Self-Determination Theory [20, 85]. For instance, athletes who perceive themselves as having autonomy regarding their training and goals are more likely to remain dedicated, regardless of their initial level of desire. Ryan and Deci [23] present similar findings, indicating that an athlete who is intrinsically motivated to compete or extrinsically motivated by the desire for recognition of their accomplishments will demonstrate higher levels of dedication if they are involved in setting personal goals and participating in the decision-making process of their training schedule. Thus, it can be inferred that fostering a robust, intimate, and highly esteemed relationship between athletes and coaches not only enhances motivation but also increases engagement in sports. Consequently, commitment serves as a bridge that links sports motivation to athletes' engagement, highlighting the importance of interpersonal relationships in sports [24, 37, 38].

Furthermore, complementarity relationships serve as a significant mediator between motivation and athletes' engagement in sports. Complementarity aligns directly with the Self-Determination Theory (SDT) proposition that competence plays a crucial role in coach-athlete relationships. Complementarity, which significantly influences athletes' perceived ability and skills, is one of the key psychological needs postulated in SDT. This is consistent with a study by Wang and Tong [46], which demonstrated that athletes with a positive attitude towards their skills derive greater enjoyment from their chosen sport. The perception of competence largely stems from the coordinated efforts between athletes and coaches. Additionally, there is evidence that the degree of interdependence in athletes' work positively contributes to their commitment, as it enhances productivity and allows athletes to observe the effectiveness of their efforts [18]. The satisfaction of the need for competence is further supported by the establishment of a collective climate where athletes can improve their performance [2]. Coaches have a crucial role in assisting athletes by offering critical feedback, helping to set realistic yet challenging goals, and ensuring that training aligns with the athletes'

abilities [25, 55]. Thus, both anticipated and actual relationships between athletes and coaches enhance motivation and sports participation through increased competence.

The current study's findings provide substantial support for Self-Determination Theory (SDT) and can help coaches create an environment favorable for promoting both intrinsic and extrinsic motivation, thereby enhancing sport engagement and performance. This approach not only boosts performance but also fosters athletes' physical and mental growth, as well as their continued engagement in sports. Thus, the current study has reinforced the role of the coach-athlete relationship in influencing sports motivation and increasing athletes' engagement in sports. Consequently, these research findings may be applicable across different cultures and countries.

While the current research provides new perspectives on how the nature of the relationship between a coach and an athlete influences motivation and athletes' engagement, it is important to recognize its limitations. First, the cross-sectional design limits the ability to establish causal relationships between motivation, the coach-athlete relationship, and engagement. Second, the study relied on self-report measures, which might have introduced certain biases, as participants may have overestimated or underestimated their levels of motivation and engagement. It may be beneficial to consider using social desirability scales as a means to address method bias in future analyses. Furthermore, in the present study, factors such as the type of sport, the highest level of sports participation, and the personality traits of athletes and coaches were not taken into consideration. Finally, future research should incorporate longitudinal designs to establish causal

links between motivation, aspects of the coach-athlete relationship, and engagement in sports. Additionally, including athletes from multiple geographical regions and sports disciplines in future studies could potentially improve the overall applicability of the findings. Future research could also explore specific patterns of coaching behaviors that influence athletes' motivation.

## Conclusions

In light of the research conclusions, the following can be stated. The coach-athlete relationship has a positive indirect effect on the relationship between motivation and engagement in sports. The current study supports the idea that the integration of both intrinsic and extrinsic motivations can positively affect athletes' level of engagement in sports, particularly when these behaviors are reinforced by coach-athlete relationships characterized by closeness, commitment, and complementarity. Conversely, amotivation negatively affects athletes' level of engagement, indicating that coaches should foster an environment that promotes the basic psychological needs of athletes. These findings suggest that the level of engagement in sports can be improved by utilizing Self-Determination Theory (SDT) through specific coaching relationships. These results provide a more comprehensive view of the delicate dynamics of the coach-athlete relationship and their impact on motivation and athletic engagement in sports.

## Acknowledgement

The authors express their sincere gratitude to the study participants for their voluntary participation and for allowing the results to be used for research purposes.

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Cite this article as:

Longakit J, Toring-Aque L, Aque Jr.F, Sayson M, Lobo J. The role of coach-athlete relationship on motivation and sports engagement. *Physical Education of Students*, 2024;28(5):268–278.  
<https://doi.org/10.15561/20755279.2024.0503>

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Received: 15.08.2024

Accepted: 15.09.2024; Published: 30.10.2024

# Mediating role of self-esteem on university students' physical activity attitude and frequency

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## Abstract

**Background and Study Aim** The benefits of physical activity for health are well known, but sometimes we fail to put that knowledge into action. There is an ongoing decline in total physical activity (PA), especially among adolescents and young women. This decline points to the need to find more effective solutions. This study aimed to determine the relationship between physical activity and attitudes toward physical activity, and also between self-esteem, body image (as subjective variables) and body mass index (as an objective variable).

**Material and Methods** This cross-sectional study measured and investigated 152 female students from various faculties in their first and second years of study at the Bucharest University of Economic Studies. The research utilized direct anthropometrical measurements and several self-reported instruments. These included questionnaires on self-esteem, body image, physical activity attitude, and a report on the frequency of physical activity. Self-esteem was assessed using the Rosenberg Self-Esteem Scale. Body dissatisfaction was evaluated using the Contour Drawing Rating Scale.

**Results** The mean Body Mass Index (BMI) value of 20.89 kg/m<sup>2</sup> indicates a healthy, normal BMI. The mean self-esteem score (31.48) falls within the normal range, but 60% of respondents could not match their actual body shape with their ideal or desired body image. 54% of respondents reported engaging in 30 minutes of physical activity, three times a week, outside the university program. As a result, the mean value of the attitude towards physical activity is slightly positive. 33% of young women's self-esteem is related to physical factors such as body image, frequency of physical activity, and attitude towards physical activity.

**Conclusions** Self-esteem mediates the correlation between body image and physical activity frequency, and even more with students' attitudes towards physical activity. The study indicates that targeted physical education programs and consistent, independent physical activity can mitigate the challenges associated with the investigated variables.

**Keywords:** body image, physical education, health, attitude

## Introduction

The decline in physical activity levels among adolescent and young adult females has become a significant public health concern. Despite widespread awareness of the benefits of physical activity, many young women fail to meet the recommended guidelines. This decline is associated with a range of negative outcomes, including poor physical health, decreased mental well-being, and issues related to body image and self-esteem. Addressing these challenges requires a deeper understanding of the factors contributing to reduced physical activity and the development of targeted interventions to promote healthier lifestyles among this demographic.

In this context, a concerning trend of diminishing overall physical activity (PA) levels has been observed with increasing age among adolescent and young adult females. The World Health Organization (WHO) [1] recommends a regular PA of 60 minutes daily for adolescents. However, it has been found

that 81% of adolescent girls are less active than boys, with 85% failing to meet the recommended level of PA [1]. This significant shortfall highlights the urgent need for targeted interventions to encourage more active lifestyles among young women.

Body image is a complex and constantly evolving concept influenced by internal and external factors, including biology, psychology, culture, and society [2, 3]. During adolescence, girls are more likely than boys to have specific concerns about weight, body shape, and self-image. Research shows that women and girls tend to have more negative experiences with body image compared to men and boys [4]. Many are discontent with their body size and weight because a slim figure is often considered the ideal standard of beauty, especially for young women. Furthermore, in adulthood, there are more underweight women than men [5]. These findings underscore the pervasive impact of societal and cultural pressures on body image, particularly among young women. There is a clear need for interventions that address these concerns. Such efforts could help improve self-esteem and overall well-being.

An important factor in adolescents' and emerging adults' negative self-evaluation is the intensive use of, or even addiction to, social media. Numerous researchers have reported a negative correlation between daily social media use and self-esteem levels [6, 7], alongside poor sleep quality, anxiety, and depression [8]. For overweight individuals, their perception of body size and volume can lead to social discomfort, shyness, low self-confidence, and an anxious posture and attitude [9]. Additionally, societal norms often associate being overweight with laziness, and overweight individuals are frequently perceived as less active. However, physical fitness is more closely linked to the frequency of physical activity rather than BMI [10]. These insights emphasize the complex interplay between social media use, body image, and physical activity.

Self-esteem is an individual's perception of self-worth, reflecting a positive or negative attitude toward oneself [11], and it is closely related to mental health [12]. An impressive amount of research has explored the positive effects of physical activity on physical and mental health, diet, and sleep [13], social integration [14], and overall well-being [15, 16]. Additionally, research has found that exercise in samples of overweight women increases self-confidence due to improvements in self-image [17]. These findings underscore the vital role of physical activity in enhancing both physical and mental health. They also highlight the importance of promoting exercise, particularly among those struggling with body image issues, to boost self-esteem and overall well-being.

Analysis of research shows that there is a concerning decline in physical activity among adolescent and young adult females, which negatively impacts both their physical and mental health. Despite the well-documented benefits of physical activity, many young women fail to meet recommended guidelines, resulting in issues related to body image and self-esteem. These problems are further compounded by societal pressures, particularly those perpetuated by social media, leading to negative self-perception and reduced physical activity levels. The complex interplay between body image, self-esteem, and physical fitness underscores the necessity for a more thorough understanding of these factors.

This study aimed to determine the relationship between physical activity and attitudes toward physical activity, and also between self-esteem body image (as subjective variables) and body mass index (as an objective variable).

## Material and Methods

### *Participants*

This cross-sectional study measured and investigated 152 female students at the Bucharest

University of Economic Studies (Romania). The participants were enrolled in different faculties and followed a weekly program of physical education classes. The age range of the participants was between 18 and 21 years, with a sample average of  $18.97 \pm 0.57$  years. The research was conducted within the context of physical education classes, with the inclusion criteria being active, weekly participation in these classes.

All participants provided informed consent prior to participation in the study. The research was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and was approved by the Ethics Committee of the Bucharest University of Economic Studies. Participants were assured of the confidentiality of their data, and all procedures were designed to minimize any potential risks or discomfort associated with participation in the study.

### *Research Design*

Direct anthropometric measurements, including height and weight, were taken to calculate Body Mass Index (BMI) and estimate whether participants fell into the underweight, healthy weight, overweight, or obese range. Subjects completed an anonymous questionnaire to assess several variables: self-esteem, body image, physical activity attitude, and self-reported data regarding physical activity frequency. Self-esteem was measured using the Rosenberg Self-Esteem Scale [18], a 10-item scale with responses on a 4-point Likert scale ranging from strongly disagree (1) to strongly agree (4). Scores were compared with the reference range of 10 to 40, and the mean value was used for statistical analysis.

To evaluate body dissatisfaction, the Contour Drawing Rating Scale (CDRS) [19] was used. This scale comprises nine drawings of a female figure, ranging from very thin (1) to very obese (9). Participants were asked to rate their ideal figure (how they would ideally like to look) and their current size (perceived figure). The difference between the ideal and perceived current size scores (current – ideal  $\neq$  0) was used to indicate body size dissatisfaction.

The frequency of physical activity was assessed by asking university students whether they engaged in physical activity three times a week. The weekly physical activity amount was quantified by the response to one question: "Do you participate in at least 30 minutes of physical activity, three times a week, in addition to the university program?" Responses were coded as 1 for NO and 2 for YES.

Attitude towards physical activity was assessed using a subscale of The Physical Education Activity Attitude Scale [20]. The original questionnaire consisted of 20 statements divided into three parts (General Attitude, Physical Education, and Scientific

Basis), from which six statements referring to students' attitudes were selected. Respondents rated these statements on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

#### Statistical analysis

Descriptive statistics were used to analyze the raw demographic data and variables. For pairs of variables, the Pearson correlation coefficient ( $r$ ) was calculated, and the coefficient of determination ( $r^2$ ) was subsequently estimated to determine the proportion of variance explained by one of the variables. IBM SPSS Statistics 20 was used for the statistical analysis, while Microsoft Excel was utilized for creating tables and figures displaying the results.

## Results

Table 1 displays the five variable values and the age of the research participants. The sample is homogeneous from the point of view of age, with teenage girls being the majority (18,92±0,57).

Data from Table 1 indicate a wide range in BMI, with most participants falling within the healthy weight range. Self-esteem levels are generally normal, though some variability is present. Body image results suggest varying levels of satisfaction, with some participants experiencing dissatisfaction. Most participants report regular physical activity, and overall attitudes towards physical activity are [generally] slightly positive.

In accordance with the data from Table 2, our results show that in the BMI distribution of the studied sample, approximately 33% of young women are situated in the underweight category, while more than 10% are classified as overweight or obese. The self-esteem mean score is 31.48, which falls within

the normal range of 25 to 35 points. However, 13 participants, representing 8.5%, scored below 25, indicating low self-esteem. Regarding body image, 62 young women (40% of the sample) are content with their body image, while the remaining 60% could not identify their body shape with their ideal or desired body image. Most respondents aspire to a thinner silhouette, with only a few expressing a desire to gain weight. Additionally, 83 out of 152 young women (almost 54%) report engaging in 30 minutes of physical activity three times a week outside the university program. Consequently, the mean value of the attitude towards physical activity is 21.81, which is slightly positive, being just 1.81 points above the neutral limit.

Data from Table 3 indicate that body image is strongly correlated with BMI and moderately correlated with self-esteem. There is also a significant relationship between the amount of physical activity and the attitude towards physical activity. Additionally, both physical activity-related variables are statistically correlated with self-esteem.

Self-esteem occupies a central position between body-related variables (BMI and body image) and physical activity variables (PA attitude and PA frequency) (Fig. 1).

## Discussion

This study aimed to determine the relationship between physical activity and attitudes toward physical activity, as well as the connection between self-esteem, body image (as subjective variables), and body mass index (BMI) (as an objective variable). The results revealed significant correlations between these variables, highlighting the central role of self-esteem in linking body-related factors,

**Table 1.** Demographic and variables descriptive statistic

| Descriptive Statistics |     |         |         |       |                |
|------------------------|-----|---------|---------|-------|----------------|
| Variable               | N   | Minimum | Maximum | Mean  | Std. Deviation |
| Age                    | 152 | 18      | 21      | 18.92 | .57647         |
| BMI                    | 152 | 15.08   | 34.20   | 20.89 | 3.45654        |
| Self Esteem            | 152 | 15.00   | 40.00   | 31.48 | 5.24622        |
| Body Image             | 152 | 1.00    | 6.00    | .9803 | 1.20962        |
| Physical Activity      | 152 | 1.00    | 2.00    | 1.546 | .49952         |
| P.A. Attitude          | 152 | 10.00   | 30.00   | 21.81 | 3.72822        |

**Table 2.** BMI distribution

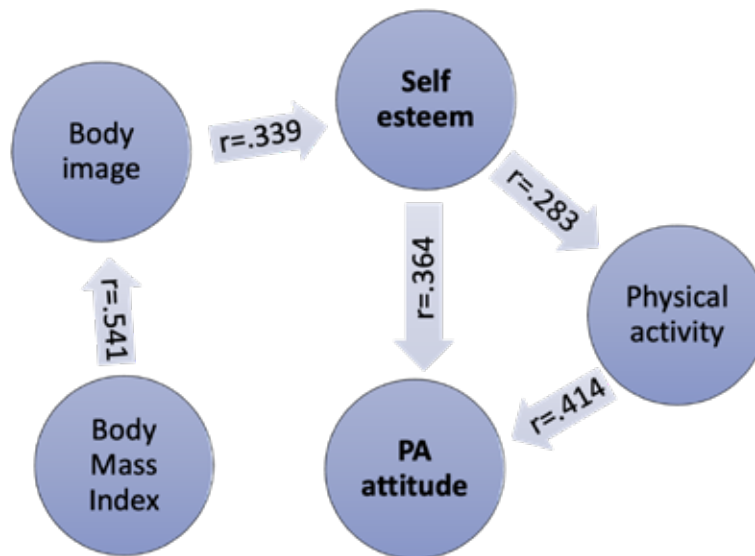
| BMI             | N (%)     |
|-----------------|-----------|
| BMI < 18.5      | 50 (32.9) |
| 18.5 < BMI < 25 | 86 (56.5) |
| 25 < BMI < 30   | 11 (7.2)  |
| BMI > 30        | 5 (3.3)   |

**Table 3.** Correlation between variables

| Variables    |                     | BMI    | Self- esteem | Body Image | Physical activity | PA attitude |
|--------------|---------------------|--------|--------------|------------|-------------------|-------------|
| BMI          | Pearson Correlation | 1      | -.155*       | .541**     | .036              | -.067       |
|              | Sig. (1-tailed)     |        | .028         | .000       | .330              | .207        |
| Self Esteem  | Pearson Correlation | -.155* | 1            | -.339**    | .283**            | .364**      |
|              | Sig. (1-tailed)     | .028   |              | .000       | .000              | .000        |
| Body Image   | Pearson Correlation | .541** | -.339**      | 1          | .051              | -.035       |
|              | Sig. (1-tailed)     | .000   | .000         |            | .267              | .336        |
| P.A          | Pearson Correlation | .036   | .283**       | .051       | 1                 | .414**      |
|              | Sig. (1-tailed)     | .330   | .000         | .267       |                   | .000        |
| P.A Attitude | Pearson Correlation | -.067  | .364**       | -.035      | .414**            | 1           |
|              | Sig. (1-tailed)     | .207   | .000         | .336       | .000              |             |
|              | N                   | 152    | 152          | 152        | 152               | 152         |

\* Correlation is significant at the 0.05 level (1-tailed)

\*\* Correlation is significant at the 0.01 level (2-tailed)



**Figure 1.** The model of variable interaction

such as BMI and body image, with physical activity behaviors and attitudes. Notably, self-esteem was found to be closely associated with both physical activity frequency and attitudes toward physical activity, underscoring its importance in promoting healthier lifestyles among young women.

A comprehensive literature review has established that engaging in physical activities and sports is directly linked to a more positive body image and reduced body dissatisfaction [2, 9, 16, 19,

21]. Conversely, lower levels of physical activity and sports participation are associated with a negative body image. In our study, 40% of the respondents reported a positive body image, which was linked to both physical and psychosocial well-being, including increased self-esteem, life satisfaction [22], and healthy behaviors. However, 60% of the young women in our sample reported a negative body image, which showed a strong correlation with BMI, particularly concerning weight.

The literature also highlights that women's frequent concerns about body image often revolve around aesthetics and physical functioning [4, 5, 22, 23]. In our sample of young women, the primary source of body dissatisfaction appears to be related to the aesthetic aspect of the body rather than its functionality. This finding aligns with other research indicating that young women are more likely to focus on the appearance of their bodies, which can significantly impact their self-esteem and overall body image.

The Sport and Physical Activity Eurobarometer survey concluded that 42% of European women between 15 and 24 never or seldom exercise or play a sport. In Romania, the percentage of sedentary young women is even higher, at 51%, and increases with age [24]. The results obtained in this research are similar to the percentages reported at the national level, with the notable difference that the female students in our study participate in at least one physical education lesson per week, engaging in at least moderate physical effort.

The data presented above confirm the attitude towards physical activity measured in our sample. Fifty-four percent of 19-year-old women reported practicing physical exercises or activities involving physical effort at least three times a week. However, it is well-documented that many girls and women fail to meet the physical activity levels recommended for good health and well-being. Studies have shown that physical activity levels tend to decrease significantly during the transition from adolescence to adulthood [25]. Our results align with these findings, as a substantial portion of our sample reported regular physical activity, but this percentage still reflects a concerning number of young women who may not be meeting the recommended levels.

In a previous survey, it was found that female students tend to prefer solitary activities for personal benefit, with limited physical contact and cooperation with teammates [26]. Despite these preferences, engaging in team sports could provide an opportunity to improve teamwork, take on responsibilities, and share experiences, knowledge, and emotions. This aligns with the current study's findings, where despite regular physical activity, students' attitudes towards physical activity and its frequency did not show a statistically significant association with physical features like BMI or body image.

After calculating the coefficient of determination ( $r^2$ ), it was found that body image is most strongly correlated with BMI, with a coefficient of determination of nearly 30% ( $r^2=0.293$ ). However, as expected, physical activity attitude and physical activity frequency were not statistically significantly associated with students' physical features such as BMI or body image. This suggests that while body image is closely linked to BMI, other factors may influence attitudes towards physical activity and the frequency of participation, indicating the complexity of these relationships. These findings are consistent with other studies on body image and BMI, as well as the role of physical activity in physical fitness regardless of BMI [9, 10].

This study is limited by its relatively small sample size and the potential biases associated with self-reported data, such as the overestimation of behaviors. Additionally, the cross-sectional nature of the study does not allow for conclusions about causality. Future research could benefit from larger, more diverse samples and longitudinal designs that track changes in physical activity, self-esteem, and body image over time. It would also be valuable to explore the role of additional factors, such as social media influence and peer relationships, in shaping these variables. Expanding the scope of research in these areas could lead to more targeted and effective interventions to promote healthy behaviors and positive self-image among young women.

## Conclusions

This study highlights the intricate connections between physical activity, self-esteem, body image, and body mass index in young women. The critical role of self-esteem in mediating these relationships suggests that interventions aimed at improving both mental and physical health should be prioritized. These findings can be particularly valuable for educators and health professionals who are working to develop programs that support the physical and psychological well-being of young women. By fostering a positive self-image and encouraging consistent physical activity, it is possible to enhance the overall well-being of young women during a pivotal stage of their development. The results also reinforce the importance of considering psychological factors when addressing physical health, advocating for a holistic approach to health promotion.

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Cite this article as:

Pop CL, Ciomag RV. Mediating role of self-esteem on university students' physical activity attitude and frequency. *Physical Education of Students*, 2024;28(5):279–285.

<https://doi.org/10.15561/20755279.2024.0504>

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Received: 17.08.2024

Accepted: 18.09.2024; Published: 30.10.2024

## Gait performance changes after ten cervical retractions

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

### Abstract

**Background and Study Aim** Students are prone to spine overloading, as they often spend prolonged periods in unfavorable postures. They tend to struggle with balancing study time and leisure physical activity. The head and neck regions are particularly rich in proprioceptors. Prolonged forward head posture (protraction) can lead to balance disturbances. This, in turn, affects gait and overall body posture. The aim of this study was to examine the effects of a series of corrective active head exercises on gait, a fundamental form of movement, in a group of healthy university students.

**Material and Methods** Gait patterns were assessed in 10 healthy male full-time students with an average age of 22.8 years (SD = 1.1). The assessment was based on the regional distribution of plantar pressure across two measurement sessions. One session was conducted before, and one after performing 10 active head retractions. Gait changes were analyzed in ten foot regions for 200 steps of each participant.

**Results** After 10 cervical retractions, a decrease in pressure, ground reaction force, contact time, and area values was observed in the 1st metatarsal head (1MTH). Conversely, an increase in these quantities was found in the toes. Additionally, there was a tendency toward a decrease in the contact area of the heel and 3rd metatarsal head (3MTH), along with increased contact time in the midfoot. Performing 10 neck retractions altered gait by inducing heel supination. It also increased hallux involvement in propulsion and widened the base of toe support.

**Conclusions** Even a few movements that correct head protraction have an immediate effect on whole-body movement. This effect suggests potential benefits of incorporating neck retractions into physical education programs for students. Even when time-consuming forms of regular exercise are not feasible, performing just a few neck-correcting movements can positively impact overall body movement.

**Keywords:** students, gait, neck, proprioception, motor control

### Introduction

Prolonged periods of sitting are a common issue among students. Poor posture, associated with extended sitting, can lead to significant musculoskeletal problems over time. Students have always been prone to maintaining unfavorable spine positions for extended periods. This posture is dictated by the need to use visual learning resources and process written information [1]. Recently, this problem has attracted greater attention due to the widespread use of smartphones for both productivity and entertainment [2]. As a result, efforts are being made to promote physical activity through sports and multidirectional therapeutic training within this social group [3, 4]. Unfortunately, not everyone is able to find time for regular training [5, 6]. Therefore, alternatives that require minimal time could provide an effective solution [7, 8, 9]. Nevertheless, most interventions aimed at increasing muscle mass or improving spine posture through body movements are typically evaluated based on repetitive training.

Evidence shows that correcting posture and reducing the symptoms of posture-related defects is possible by regularly performing specific short movements over an extended period [10, 11]. However, no studies have examined the immediate effects of a few active movements that correct head and neck posture on the overall movement system. Despite the importance of such research for developing guidelines for effective interventions, the influence on the entire body remains unstudied.

Head position and the shape of the cervical spine are important factors in the pathogenesis of discopathy and undiagnosed neck or head pain. These conditions are often associated with the loss of cervical lordosis [12, 13, 14, 15]. Patients with decreased cervical lordosis tend to experience longer episodes of headaches compared to those without this postural disturbance [16]. The reading position significantly influences the alignment of all sections of the spine in the sagittal plane [2]. Therefore, various therapeutic and preventive interventions are recommended. Since it has been emphasized that repetitive movements influence muscle development, studies have examined the outcomes of long-term programs aimed at correcting head

posture [17]. It has been found that regularly repeated movements to correct head posture have a positive effect [18]. Many therapeutic techniques involve passive movements of the patient's neck, aiming to produce immediate changes in pain perception and body control. Some of these techniques, like Glisson's cervical traction belt, have been used for a long time. Others, such as suboccipital muscle traction [8, 19] or various massage methods, including the suboccipital muscle inhibition technique, were introduced more recently. Only the "Mechanical Diagnosis and Therapy" method, known as the McKenzie method, uses repeated cervical retractions to treat and diagnose neck pain. The rationale for using repetition is based solely on the local modification of pressure distribution in the intervertebral discs [20, 21, 22]. However, the effects of these interventions in previous studies were assessed after multiple repeated movement sessions. Successful application of these methods requires that subjects allocate sufficient time for the exercises.

Meanwhile, it has been noted that even temporary increases in head load caused by forward head posture can disrupt proprioception. This disruption contributes to difficulties in correcting head posture, especially in individuals with more pronounced forward head protraction [4]. This phenomenon is unique to the neck, explained by the higher spindle density in neck muscles, which allows them to receive a greater number of proprioceptive signals [23]. Head position affects balance [24]. It influences overall posture through multisensory contributions to visuospatial orientation, as the interaction between neck and trunk proprioception has been confirmed [25]. The mutual dependence between gait motor control and head position has been established in only a few studies and remains unclear [26]. This dependence is demonstrated by changes in gait caused by uneven ground, which lead to the stabilization of head position during walking [27]. Additionally, changes in gait have been observed in specific head positions [28]. Therefore, movements that correct neck alignment are likely to reduce the strain imposed on the spine by maintaining unfavorable long-term positions. This observation may also explain the immediate relief experienced after various physiotherapeutic interventions targeting the neck.

Taken together, prophylactic solutions that require little time are highly sought-after. The heretofore proposed recommendations are time-consuming and, as a result, not widely followed by busy students. Despite numerous studies highlighting the benefits of regular physical activity and posture correction exercises, the challenge remains in developing interventions that are both effective and feasible for students. Many existing therapeutic approaches, while beneficial, require sustained effort and regular practice over long

periods. This limits their widespread adoption. Therefore, there is a clear need for simpler, more time-efficient methods. Such methods should provide both immediate and long-term relief from the negative effects of prolonged poor posture, particularly in the student population.

Analysis of research findings allows us to propose the following hypothesis: Performing even a few movements that correct head posture has an immediate effect on body alignment. This leads to improved posture, which, in turn, affects walking conditions and gait performance.

The aim of this study was to examine the effects of a series of corrective active head exercises on gait, a fundamental form of movement, in a group of healthy university students.

## Materials and Methods

### *Participants*

Ten male full-time university students participated in the study. The participants reported no health issues and showed no visible signs of conditions that could affect musculoskeletal function. The group was characterized by the following parameters: age – 22.8 (SD = 1.1) years, mass – 76.75 (SD = 6.81) kg, height – 179.6 (SD = 0.04) cm, and BMI – 21.58 (SD = 2.44) kg/m<sup>2</sup>.

Each participant provided informed consent prior to the study, which was conducted in accordance with the guidelines of the Declaration of Helsinki. The study protocol was approved by the institutional review boards of the Ethics Committee of the Poznan University of Medical Sciences (Act 1068/16, Archived Number 10/November/2016).

### *Study Design*

To assess the impact of a series of cervical spine extension movements on gait, individual walking patterns were compared before and after performing a few movements aimed at straightening the cervical spine. The interactions between different anatomical-functional areas of the foot and the ground during weight shifting in free gait were measured for comparison.

*Equipment.* To measure changes in plantar pressure, an emed-m pedobarometric platform (Novel, Munich, Germany) was used. The platform, with an active area of 395 × 240 mm, was equipped with 3792 capacitance-based force transducers, providing a resolution of 4 sensors/cm<sup>2</sup>. It was embedded in a 5-meter walkway. The platform was paired with Novel software, which collected measurement data at a frequency of 100 Hz and performed preliminary analysis of the temporal-spatial distribution of foot plantar pressures.

*Measurement protocol.* The measurements were conducted between 8 AM and 1 PM. The course of the experiment is presented in Figure 1. The experiment consisted of four stages:

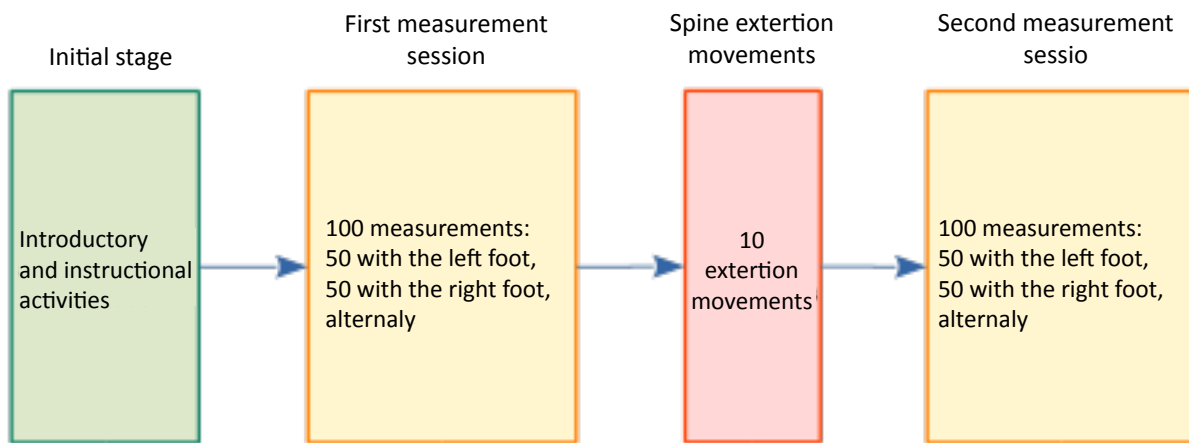
1. The initial stage, including introductory and instructional activities,
2. The first measurement session,
3. Performing a series of cervical spine extension movements,
4. The second measurement session.

At the initial stage, all participants were thoroughly instructed on how to enable data collection. They performed several practice walk-throughs to master the second-step method [29]. According to this method, the participant takes the first step in front of the platform and the second step onto the platform, where the pressure characteristics are recorded. Participants were also guided on how to arrange the optimal starting distance from the platform, which is essential for executing the second-step protocol correctly. This process familiarized the participants with an optimal walking rhythm [30], which minimized measurement errors caused by the tendency to place greater load on the first step. All participants took part in both measurement sessions. In each session, every participant completed 100 passes over the measuring platform - 50 passes with the right foot and 50 with the left foot, alternating between the two. Before the second session, each participant

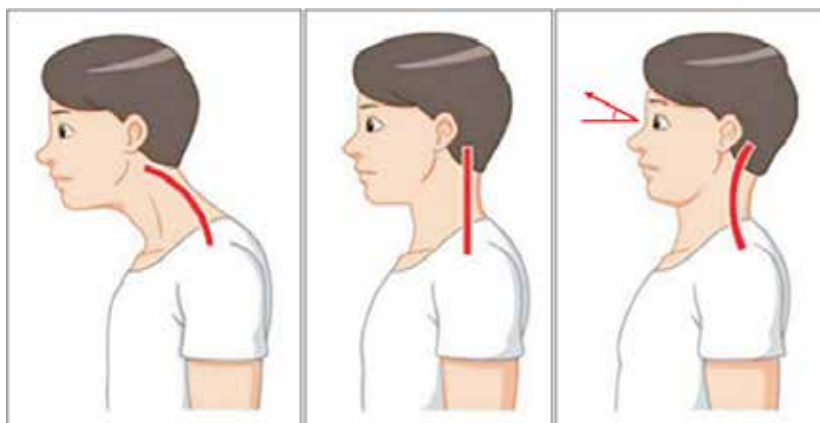
performed 10 cervical spine retractions in a seated position (Figure 2).

*Data extraction.* The artificial intelligence algorithms in the Novel emed-m software automatically identified specific anatomically functional areas of the foot from the plantar images. These areas, referred to as “masks,” were generated based on the distribution of plantar pressures in each measurement. The Novel software, integrated with the platform, isolated ten such masks, corresponding to: 1 - heel (H), 2 - midfoot (MF), 3-7 - the five metatarsal heads (MTH1–MTH5), 8 - hallux (first toe), 9 - second toe, 10 - third to fifth toes, and 0 - the entire foot surface. Files generated by the measuring system were processed using Novel’s Multimask and Groupmask Evaluation programs, allowing for preliminary statistical and numerical analysis.

The text files representing the measurement results, generated by the system, were processed using the AWK programming language. The program was used to extract the desired index values in a format suitable for subsequent numerical processing. The extracted values included maximal (*mx*) and mean (*me*) contact area [cm<sup>2</sup>], mean force (*mef*) [N], contact time (*ctm*) [s], and percentage of contact time (*ctp*) [%], which



**Figure 1.** The course of the experiment.



**Figure 2.** Cervical spine retraction movement [31].

represents the ratio of the *ctm* of a single mask to the *ctm* of the entire foot.

#### Statistical Analysis

The analyses and charts were developed using the R Language and Environment for Statistical Computing [32]. Initial results were assessed qualitatively before the measurement data underwent statistical description and further analysis. The statistical tests applied included the Kendall rank correlation test and the Shapiro–Wilk test.

A Kendall rank correlation test of the measured values, conducted across 400 50-sample sets of measurements (10 participants × 2 feet × 10 masks, tested twice), showed no observable learning effect. The extreme mean value of Kendall’s Tau coefficients for these sets, grouped by individual masks, was -0.1 [-0.15, -0.04]. Additionally, a Kendall rank correlation test of stance phase time with other measured quantities indicated no significant influence of gait velocity on the measured parameters. A Shapiro–Wilk test for normality did not reveal strong deviations from a normal distribution in the measurement data.

To enable proper comparison of parameter values across different individuals, the collected data was normalized, and the percentage mean pressure (*pmp*) index was calculated [33]. This index is defined as the percentage ratio between the mean pressure values for specific masks and the total value for all recorded areas of plantar pressure, as described by the following formula (1), with the abbreviations:

- $mef_n$  – mean force for mask  $n$ ,
- $mef_0$  – mean force for the entire foot,
- $mxan$  – maximal area for mask  $n$ ,
- $mxao$  – maximal area for the entire foot.

$$pmp_n = 100 \cdot \frac{\frac{mef_n}{mxan}}{\frac{mef_0}{mxao}} = 100 \cdot \frac{mef_n \cdot mxao}{mef_0 \cdot mxan} \quad (1)$$

This index represents the contribution of different foot parts to body weight shifting during each step. For the assessment of mean area (*mea*), normalization was performed using formula (2), with the following abbreviations:

- $mean$  – mean area for mask  $n$ ,
- $meao$  – mean area for the entire foot.

$$pa_n = 100 \cdot \frac{meao}{mean} \quad (2)$$

To minimize the effects of outliers that could occur due to non-standard events, which may have been missed during the measurement, all datasets were subjected to adaptive winsorisation. This procedure defines outliers as values outside the range between the lower limit, calculated as the difference between the first quartile and 1.5

times the interquartile range, and the upper limit, calculated as the sum of the third quartile and 1.5 times the interquartile range. The winsorisation process adjusts these outliers to the extreme values of the lower and upper limits of the defined interval. The relative change in the values of the analysed indices due to the retraction exercise was estimated using the following formula (3):

$$RC(x_1, x_2) [\%] = \ln\left(\frac{x_2}{x_1}\right) \cdot 100 \quad (3)$$

where:

- $x_1$  – value from the first measurement session,
  - $x_2$  – value from the second measurement session,
- and these values were visualized using boxplots and point-and-whisker charts.

The Cliff’s  $\delta$  effect size [34] of this change was also calculated. Using the orddom function [35], the Cliff’s  $\delta$  effect size was determined according to the following formula (4):

$$\delta(x) = \frac{\sum_{i=1}^n \text{sign}(x_i)}{n} \quad (4)$$

where:

- sign – the sign function of a number,
- $n$  – sample size, and the  $p$ -value of the null hypothesis for Cliff’s  $\delta$ .

All analyzed datasets were described by their means and 95% confidence intervals (CIs), with the interval boundaries presented in square brackets ([Clower, Clupper]).

## Results

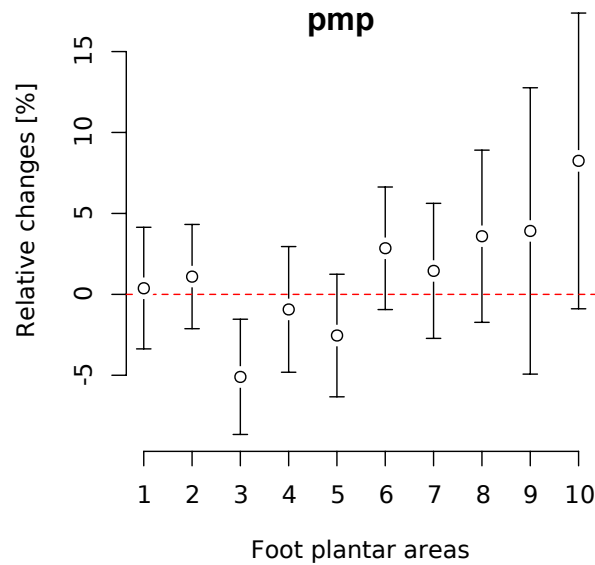
For all the analyzed indices, namely pressure, force, area, and time, a consistent change in the gait pattern was observed. There was a decrease in values for the 1st metatarsal head (1MTH) and an increase in values across all the toes. A reduction occurred in the contact area of the heel and the 3rd metatarsal head (3MTH), while the contact time of the midfoot increased.

### Pressure

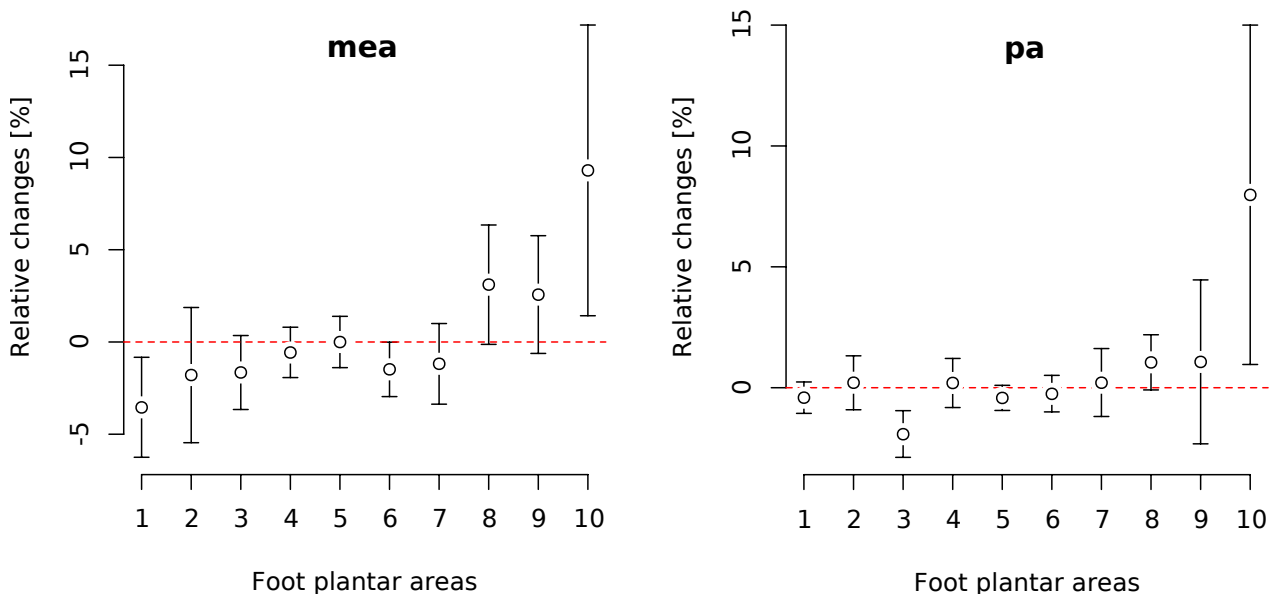
The assessment of weight-shifting engagement showed a decrease for mask 3 (1MTH) and an increase for masks 6-10, which correspond to the 4th and 5th metatarsal heads (4MTH, 5MTH) and the toes (Figure 3). Figure 3 demonstrates: A notable decline in gait engagement is evident for the 1MTH (mask 3), while a modest enhancement in the engagement is observed for the 4-5 MTH and the third to fifth toes (mask 10).

### Contact area

The area of contact decreased for masks 1, 2, 3, 6 and 7 (heel, midfoot, 1MTH, 4MTH and 5MTH), while it increased for masks 8 and 10 (hallux and toes 3-5), as shown in Figure 4. The contact area generally shifted to the toes. The absolute values (*mea*) decreased



**Figure 3.** The effect of cervical retraction exercises on the pattern of weight shifting, as evidenced by alterations in the *pmp* index: The whiskers around each point represent 95% confidence intervals.



**Figure 4.** The effect of cervical retraction exercises on the pattern of weight shifting, as evidenced by alterations in the non-normalise *mea* and the normalised *pa* indices of the area of contact with the ground: The whiskers around each point represent 95% confidence intervals.

most prominently for the heel, but in the pattern expressed by relative values (*pa*) - the decrease was the most pronounced for mask 3 (1MTH). The contact area for the whole foot remained unchanged (*mea*) group mean difference 0.06[-0.59 0.71],  $\delta = 0.1$  [-0.35 0.512], ( $p = 0.666$ ). Figure 4 demonstrates: A reduction in ground contact is evident for the 1MTH (mask 3), while a notable decline is observed for the heel (mask 1) and the 3MTH (mask 5). Conversely, there is an increase in the contact area for the hallux (mask 8) and the 3-5 toes (mask 10).

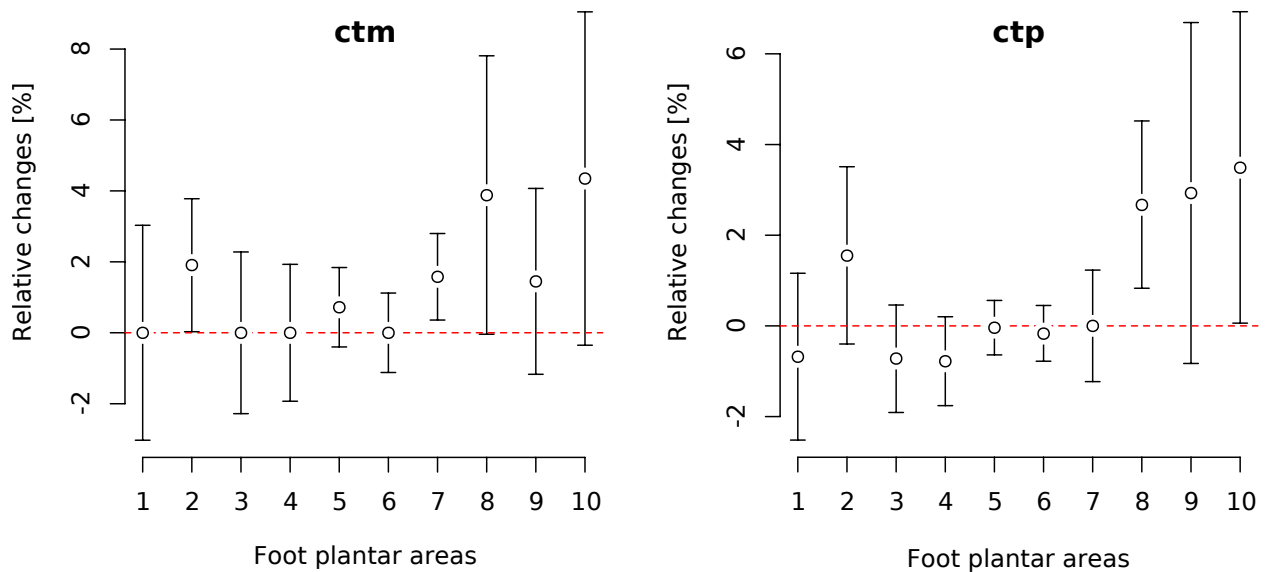
#### Contact Time

The contact time increased for masks 2 and 7-10 (midfoot, 5MTH, and the toes) in both absolute (*ctm*) and relative values (*ctp*), as shown in Figure 5.

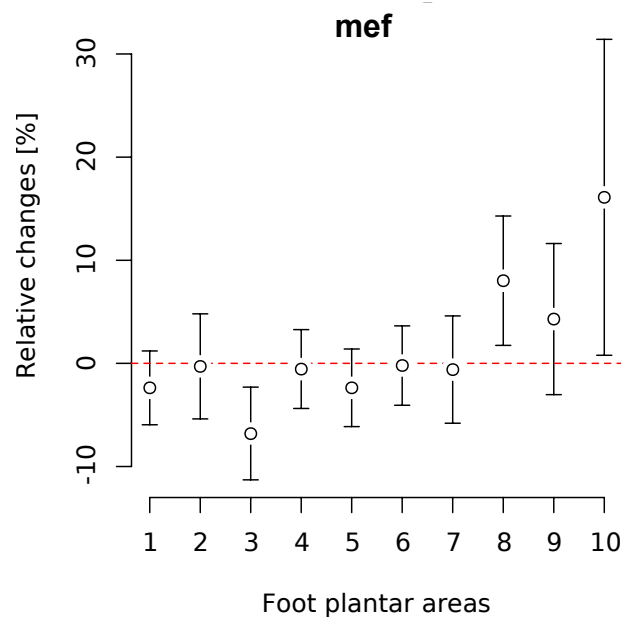
Contact time for the whole foot remained unchanged (*ctm* group mean difference 1.8 [-0.2 3.79],  $\delta = 0.2$  [-0.24 0.57],  $p = 0.359$ ). Figure 5 demonstrates: The increase in contact time is most evident for hallux (mask 8). Furthermore, a discernible enhancement in this interval is evident for midfoot (mask 2) and toes.

#### Ground reaction force

The ground reaction force (*mef*) decreased for masks 1 (-2.37 [-5.95 1.21]  $\delta = -0.4$  [-0.73 0.079]  $p = 0.072$ ) and 3 (-6.8 [-11.3 -2.3]  $\delta = -0.4$  [-0.73 0.079]  $p = 0.072$ ) and increased for masks 8, 9 and 10, as shown in Figure 6 meaning that the heel and 1MTH loads decreased and toes loads in the gait performance increased. For the whole foot, *mef*



**Figure 5.** The effect of cervical retraction exercises on the pattern of weight shifting (alterations in the non-normalised *ctm* and the normalised *ctp* indices of time of contact with the ground): The whiskers around each point represent 95% confidence intervals.



**Figure 6.** The effect of cervical retraction exercises on the pattern of weight shifting (alterations in the non-normalised *mef* index of the force of interaction with the ground): The whiskers around each point represent 95% confidence intervals.

remained unchanged (*mef* group mean difference 0.02 [-0.42 0.47],  $\delta = 0$  [-0.43 0.43],  $p = 1$ ). Figure 6 demonstrates: The increase of the contact time is most evident for 1MTH (mask 3). A discernible enhancement in the force is also evident for toes.

The numerical analysis of the effect of retractions on the relative changes was performed on normalised indices *pmp*, *ctp*, and *pa* (Table 1). Table 1 demonstrates: The most prominent positive changes were seen for mask 3 (1MTH), while the most notable negative changes were found for mask 10 (3-5 toes) across all normalised indices. Although less evident, consistent growth was observed for masks 8 (halux) and 9 (second toe).

## Discussion

To promote the prevention of posture disturbances among students, it is essential to conduct studies that assess the effectiveness of a few movements aimed at correcting protracted head posture, which often results from non-ergonomic positions during computer use, reading, or writing. Given the influence of head position on proprioception, it was hypothesized that even a small number of neck retraction repetitions would affect the gait pattern. After performing 10 neck retractions, gait assessment in a group of students revealed a multidimensional decrease in values at

**Table 1.** The effect of the retraction exercises in relative changes of the values of the normalized indices: *mmp*, *ctp* and *pa*. 95% confidence intervals (CIs) are presented in square brackets [CI<sub>lower</sub> CI<sub>upper</sub>].

| m  | pmp                   |                        |      | ctp                   |                        |      | pa                     |                       |      |
|----|-----------------------|------------------------|------|-----------------------|------------------------|------|------------------------|-----------------------|------|
|    | Mean                  | $\delta$               | p    | Mean                  | $\delta$               | p    | Mean                   | $\delta$              | p    |
| 1  | 0.38<br>[-3.37 4.14]  | 0.1<br>[-0.35 0.51]    | 0.67 | -0.68<br>[-2.52 1.16] | -0.15<br>[-0.543 0.30] | 0.51 | -0.41<br>[-1.06 0.24]  | -0.2<br>[-0.59 0.26]  | 0.39 |
| 2  | 1.1<br>[-2.12 4.32]   | 0<br>[-0.433 0.43]     | 1    | 1.55<br>[-0.40 3.51]  | 0.25<br>[-0.207 0.62]  | 0.26 | 0.21<br>[-0.91 1.32]   | 0.1<br>[-0.35 0.512]  | 0.67 |
| 3  | -5.1<br>[-8.66 -1.54] | -0.5<br>[-0.793 -0.02] | 0.02 | -0.72<br>[-1.91 0.46] | -0.3<br>[-0.661 0.17]  | 0.19 | -1.92<br>[-2.88 -0.95] | -0.5<br>[-0.79 -0.02] | 0.02 |
| 4  | -0.93<br>[-4.81 2.95] | -0.3<br>[-0.661 0.17]  | 0.19 | -0.78<br>[-1.76 0.2]  | -0.25<br>[-0.617 0.21] | 0.26 | 0.2<br>[-0.82 1.21]    | 0.1<br>[-0.35 0.51]   | 0.67 |
| 5  | -2.54<br>[-6.33 1.24] | -0.2<br>[-0.588 0.26]  | 0.39 | -0.04<br>[-0.64 0.56] | -0.05<br>[-0.464 0.38] | 0.83 | -0.42<br>[-0.94 0.1]   | -0.3<br>[-0.66 0.17]  | 0.19 |
| 6  | 2.85<br>[-0.94 6.63]  | 0.2<br>[-0.263 0.59]   | 0.39 | -0.17<br>[-0.78 0.45] | -0.15<br>[-0.543 0.30] | 0.51 | -0.25<br>[-1 0.51]     | -0.2<br>[-0.59 0.26]  | 0.39 |
| 7  | 1.45<br>[-2.72 5.62]  | 0.2<br>[-0.263 0.59]   | 0.39 | 0<br>[-1.23 1.23]     | -0.05<br>[-0.45 0.36]  | 0.82 | 0.21<br>[-1.19 1.62]   | 0.2<br>[-0.26 0.59]   | 0.39 |
| 8  | 3.59<br>[-1.73 8.91]  | 0.3<br>[-0.173 0.66]   | 0.19 | 2.67<br>[0.83 4.52]   | 0.55<br>[0.09 0.82]    | 0.01 | 1.05<br>[-0.09 2.19]   | 0.3<br>[-0.17 0.66]   | 0.19 |
| 9  | 3.92<br>[-4.93 12.76] | 0.1<br>[-0.35 0.51]    | 0.67 | 2.93<br>[-0.83 6.69]  | 0.2<br>[-0.26 0.59]    | 0.39 | 1.07<br>[-2.32 4.46]   | 0.2<br>[-0.26 0.59]   | 0.39 |
| 10 | 8.25<br>[-0.89 17.38] | 0.5<br>[0.02 0.79]     | 0.02 | 3.49<br>[0.06 6.93]   | 0.4<br>[-0.08 0.73]    | 0.07 | 7.98<br>[0.96 15]      | 0.4<br>[-0.08 0.73]   | 0.07 |

the 1st metatarsal head (1MTH) and an increase in values at the toes. Additionally, the performance of these movements led to a reduced contact area in the heel and 3rd metatarsal head (3MTH), along with an extension of contact time in the midfoot.

A decrease of approximately 5% in 1MTH engagement in weight-shifting ( $\delta = 0.5$ ,  $p = 0.02$ ) was recorded, along with a tendency for increased engagement of the lateral metatarsal heads (MTHs) and all toes in this process (for toes 3-5,  $\delta = 0.5$ ,  $p = 0.02$ ) (Table 1). These changes were associated with a shift of approximately 5% in ground reaction force (*mef*) from 1MTH to the hallux and toes 3-5. Additionally, a decrease in the contact area by several percent (*mea*, *pa*) was observed in masks 1 (heel), 3 (1MTH), and 5 (3MTH), while an increase occurred in masks 8 (hallux) and 10 (toes 3-5). These dynamics indicate that changes in pressure and force were accompanied by a shift in foot positioning on the ground. As the contact area of the heel decreased without a corresponding reduction in load, this change was attributed to a more supine position of the calcaneal tuberosity. The increased contact time in the midfoot and across the entire foot supports the idea of a more supine weight transfer through the foot after performing cervical extensions. The plantar pressure distribution analysis suggests a shift towards a more supine foot position, increased hallux engagement in propulsion, and greater reliance on the toes for support. These outcomes suggest that even a brief deepening of cervical

lordosis during extension can alter gait patterns.

This study is the first to demonstrate immediate changes in gait resulting from just a few corrective head movements. Similar analyses have not been conducted to date [26], which is why the observed gait pattern changes can only be compared to the effects reported in studies focusing on regularly repeated training targeting the neck region [17]. As in those studies, the intervention involving the neck led to expected changes. However, it is surprising that alterations in plantar pressure distribution occurred after only a few corrective movements. Considering the existing reports on the influence of neck and head alignment on proprioception and balance [24], these observed changes become more comprehensible. The results indicate that even a brief deepening of cervical lordosis during extension can immediately alter proprioceptive conditions, affecting motor control processes. Thus, it was found that performing just a few movements to correct head position has an impact on the entire body, leading to changes in gait.

The existing evidence supports the direction of the observed changes. Heel positioning is considered a critical factor in influencing the conditions of propulsion [36]. The midfoot plays a significant role in power generation during walking. Pronation and plantarflexion moments in this area are related to the foot's resistance to supination. Lower resistance to supination, in turn, enhances the midfoot's power generation capacity. Given this, the observed

effect of achieving a more supine heel position through head alignment correction likely creates more favorable conditions during the stance phase of gait. This is especially relevant in the context of ankle joint stability, which, when compromised, can lead to injuries.

The observed shift in load toward the toes, particularly the hallux, aligns with recent studies investigating the “windlass mechanism” in foot function. These studies highlight the importance of dorsiflexion at the intermetatarsal joint (IMTJ) for effective propulsion [37]. However, adequate force generation under the hallux is crucial for this flexion to contribute to propulsion. We observed an increase in this force generation ability after performing neck extensions. This result underscores the significant role of the neck region in regulating propulsion conditions. It is consistent with findings from a study showing that a lateral head position reduced propulsion efficiency on the side toward which the head was leaned [28]. The results presented here suggest that performing just a few neck posture correction movements creates favorable conditions for subsequent movement activities. In gait, these movements enhance weight-shift efficiency, leading to a more supine heel position and greater hallux engagement in propulsion. Thus, we found that even a small number of neck posture correction movements can positively influence locomotion dynamics.

In our study, the benefits of performing even a few head and neck posture-correcting movements highlight their usefulness during periods of excessive loading, such as those caused by forward head posture. The fact that the corrective effect occurs immediately after just a few movements helps explain the instant benefits of therapeutic techniques that involve or facilitate neck extension, such as muscle relaxation. Therefore, studies on therapeutic interventions should prioritize neck

extensions before considering other techniques to avoid overlapping effects. For individuals who spend hours working or studying at a desk, performing neck extensions throughout the day should become a routine practice, not only for its positive impact on the structural elements of the neck but also for the significant influence it has on the motor control of the entire body, as demonstrated in our findings.

While this study demonstrated the immediate benefits of neck posture-correcting movements on gait and motor control, certain limitations should be acknowledged. The sample size was relatively small and limited to healthy university students, which may affect the generalizability of the findings. Future research should involve larger, more diverse populations and investigate the long-term effects of these corrective movements. Additionally, further studies are needed to explore the interaction between neck extensions and other therapeutic techniques to better understand their combined impact on posture and movement control.

## Conclusions

Performing just a few neck movements, such as retractions, significantly alters gait and has a direct impact on the overall condition of the body. This simple intervention is sufficient to induce heel supination, increase hallux engagement in propulsion, and widen the base of foot support through greater toe involvement. Therefore, even a small number of corrective head movements have therapeutic benefits and contribute to the prevention of postural-related disorders by influencing whole-body movement. Short sequences of neck-extension movements, even when performed occasionally, should be incorporated into students’ physical education programs. These exercises have the potential to benefit individuals who are prone to overloading due to prolonged periods of forward head posture during computer use or reading.

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Cite this article as:

Latour E, Latour EE, Nowaszczuk J, Arlet J, Zavatska L. Gait performance changes after ten cervical retractions. *Physical Education of Students*, 2024;28(5):286–295. <https://doi.org/10.15561/20755279.2024.0505>

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Received: 12.08.2024

Accepted: 23.09.2024; Published: 30.10.2024

## The effect of sports specific warm-up on lower and upper extremity visual response time in female athletes

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

### Abstract

**Background and Study Aim** Response time is one of the important parameters affecting performance in sports. The aim of this study was to investigate the visual response time of the upper (hand) and lower (foot) extremities after a warm-up activity applied to female football and volleyball players.

**Material and Methods** Eleven female football players and eleven volleyball players, aged  $19.27 \pm 1.93$  years, with a height of  $164.90 \pm 8.07$  cm, body weight of  $57.00 \pm 6.01$  kg, and  $6.40 \pm 2.36$  years of sports experience, participated in the study as volunteers. Visual response times for the upper and lower extremities were measured before and after the warm-up protocol. The warm-up began with static stretching exercises for 2 minutes. This was followed by aerobic jogging for 2.5 minutes at a heart rate of approximately 140 beats per minute. After that, activities involving dynamic joint mobility were performed for 5 minutes. Finally, a 2.5-minute, three-stage sport-specific warm-up was completed. In total, the warm-up protocol lasted 17 minutes.

**Results** Volleyball players' upper extremity visual response time did not show significant differences before and after warm-up ( $Z = -1.561$ ,  $p = 0.119$ ). Significant differences were found in the upper extremity visual response time of football players before and after warm-up ( $t = 2.887$ ,  $p = 0.016$ ). No significant difference was found in the comparison of volleyball and football players' pre-warm-up ( $t = 1.905$ ,  $p = 0.071$ ) and post-warm-up ( $U = 43.000$ ,  $p = 0.247$ ) two-hand visual response times. A significant difference was found in the comparison of volleyball players' lower extremity visual response times before and after warm-up ( $Z = -2.674$ ,  $p = 0.007$ ). No significant difference was found in the comparison of lower extremity visual response times of football players before and after warm-up ( $t = 2.132$ ,  $p = 0.059$ ). A significant difference was determined in the comparison of lower extremity visual response times of volleyball and football players before warm-up ( $t = 3.307$ ,  $p = 0.004$ ) and after warm-up ( $U = 20.000$ ,  $p = 0.008$ ).

**Conclusions** The findings highlight the importance of sport-specific warm-up protocols in preparing athletes for optimal performance. Implementing appropriate warm-up strategies can therefore be a key factor in maximizing athletic performance and maintaining long-term physical health in female athletes.

**Keywords:** female, response time, football, volleyball, warm up.

### Introduction

In competitive sports, quick and efficient response times are crucial for optimal performance. Athletes rely heavily on both upper and lower extremity visual response times to react to dynamic and unpredictable situations during play. Understanding how these warm-up protocols influence reaction times could provide valuable insights for improving athletic performance and reducing the risk of injury. Therefore, it is essential to investigate the impact of targeted warm-up exercises on visual response times in both the upper and lower extremities.

In this context, warm-up activities affect the athlete's physiological and psychological performance before training and competition,

regardless of the sport branch [1]. Although warm-up can have various interpretations, it is commonly understood as preparation for any training session or competition [2]. In sports, the term "warm-up" is defined as a preparatory exercise period that aims to improve performance in the following competition or training session [3]. Warm-up is essential for achieving maximum efficiency from the athlete. It also plays a key role in preventing injuries [4]. Warming up before training or competition creates beneficial changes in the athlete's physical condition, reducing the risk of injury. For example, a 15–20-minute warm-up helps reduce muscle stiffness and shortens muscle contraction time. It also facilitates oxygen utilization, prepares the heart for intense activity, and mentally prepares the athlete for training or competition [5].

Athletes generally prefer a warm-up protocol that begins with moderate running, followed by

static stretching. Some studies suggest that static stretching before exercise improves posture, reduces the risk of injury, and enhances performance [6]. To achieve maximum performance, it is important for athletes to reach an optimal level both physically and psychologically. As a result, the pressure, stress, and anxiety on athletes are often very high. Under this pressure, athletes must maintain their motor skills at the best possible level to make quick decisions [7].

One of the most important of these behaviors is reaction time (response time), which is a key parameter for performance [8]. Reaction time refers to the interval between the onset of a stimulus at the receptor and the moment the muscle responds with an action [9]. Achieving the best results in sports undoubtedly requires a high level of cognitive, perceptual, motor, and physical abilities. Compared to most other activities, sports competitions place significant demands on the visual system [10].

The visual system is the most complex of all sensory systems. It plays a dominant role by generating feedback and influencing other sensory systems. Good vision involves exceptional perceptual abilities, where information is gathered through the eyes and sent to the brain. The brain then interprets this information and initiates the appropriate physical actions [11].

The sense of vision accounts for 80% to 90% of all human sensory information. As a result, researchers are increasingly recognizing the importance of visual perception as a key factor influencing athletes' performance in sports. Effective collection and analysis of data from both central and peripheral vision can significantly impact athletes' coordination and motor abilities [12].

In summary, numerous studies have highlighted the critical role of warm-up protocols, visual perception, and reaction time in enhancing athletic performance and reducing the risk of injury. Research has demonstrated that both static stretching and sport-specific warm-ups can positively influence athletes' physical and cognitive readiness. Additionally, the importance of the visual system in coordinating motor responses has been well-established. However, despite these findings, there remains a need for more detailed studies to fully understand the specific effects of warm-up activities on visual response times, particularly in different sports and among female athletes.

Therefore, the aim of this study was to examine the effects of warm-up activities specific to hand-based sports (e.g., volleyball) and foot-based sports (e.g., football) on visual response time. Additionally, the study aimed to evaluate the applicability of these activities across different sports branches based on the results obtained.

## Materials and Methods

### *Participants*

A total of 22 female athletes (11 football and 11 volleyball players) participated in the study. Nineteen of the participants were university students. The athletes' average age was  $19.27 \pm 1.93$  years, with an average height of  $164.90 \pm 8.07$  cm, body weight of  $57.00 \pm 6.01$  kg, and  $6.40 \pm 2.36$  years of sports experience. Before the study, the purpose and the tests to be conducted were explained to all participants in detail. Additionally, the Voluntary Consent Form, which provided information about the study, was read to the athletes, and their written consent was obtained. Ethics Committee approval for this study was obtained from the Selçuk University Faculty of Sports Sciences, Non-Interventional Clinical Research Ethics Committee.

### *Study Design*

#### *Warm-up Activity*

The warm-up activity lasted a total of 17 minutes. It began with static stretching exercises targeting the thigh, calf, shoulder, and hip muscles for 2 minutes, with participants holding each stretch for 15 seconds at the end of the range of motion. This was followed by 2.5 minutes of aerobic jogging, during which participants maintained a heart rate of approximately 140 beats per minute. Finally, dynamic joint mobility exercises were performed for 5 minutes. These activities included lateral and circular movements of the hips, up-and-down, back-and-forth, and open-and-close movements of the arms. They also involved jumping up and tapping the feet on the hips, swinging the trunk backward from the right and left sides, side running with knee lifts, and cross-stepping in both directions. Additionally, vertical and lateral jumps, as well as accelerated sprints, were performed. Afterward, a 3-stage sport-specific procedure lasting 2.5 minutes was performed for each group [13, 14]. For volleyball players:

- 1) Finger and cuff passes,
- 2) Forward, right, and left blocking,
- 3) Ball reception and spiking.

For football players:

- 1) Short and long passes,
- 2) Dribbling,
- 3) Shooting exercises.

Visual reaction time measurements were taken within 5 minutes after the warm-up protocol ended. Passive rest periods of 1 minute were given at the end of the sessions.

#### *Visual Response Time*

The research group participated in measurements to determine visual response time both before and after the warm-up. To minimize learning and practice effects, participants were randomly

assigned to upper extremity (hand) or lower extremity (foot) tests. Response times were then measured using the Light Trainer Pro system (Light Trainer® Visuo-Motor Devices Company). This device consists of a light disc with 8 RGB LEDs that can be controlled via a tablet or smartphone (Figure 1). It was used to measure reaction time based on the athletes deactivating the illuminated disc. This measurement protocol was adapted from [15] and [16]. Six discs were mounted on a flat iron platform, with magnets on the back of the discs to determine hand visual reaction time. The discs were placed at three different distances from the participant's hand: zero, shoulder, and random distances. For the zero distance, a light disc was mounted on the platform, and the participant was instructed to place their hand right next to the disc (with both hands together) to perform the test.

For the shoulder distance, the participant was instructed to place the tested hand one shoulder-width away from the light disc. Participants stood facing the iron platform at arm's length and were instructed to raise their arms to chest level, with their palms lightly touching the platform (starting position). They were then instructed to deactivate the lights as quickly as possible by bringing their hands close to the flashing light (within 10 cm). After switching off the light, participants had to return their arms to the starting position. The measurements were configured using the smartphone controller, and a 30-second rest was given between each trial. Visual response time (in milliseconds) for the hands, both before and after

the warm-up, was recorded by the device. Three measurements were taken for each hand, and the averages were used in the analyses. The lower extremity (foot) measurement protocol was adapted and organized according to [17].

The following instructions were given to the participants for the lower extremity task. Participants were randomly positioned in a semicircle with both feet to respond to a visual stimulus and deactivate a series of 5 targets, in order to minimize learning and practice effects. They stood in front of a 180° semicircle, with each light disc placed at 45° increments around the semicircle. The distance of the lights, numbered 1 to 5, was adjusted according to each participant's leg length. After extinguishing each light, participants were instructed to return their feet to the starting position.

#### Statistical Analysis

All measurements in the study were presented as mean and standard deviation (Std. Deviation). Based on the results of the normality distribution, the independent t-test and Mann-Whitney U test were used to compare two independent groups, while the paired t-test and Wilcoxon test were used to compare two dependent groups. Statistical data were analyzed using the SPSS (version 22.0) software package.

## Results

Figure 2 shows the hand visual response times of volleyball and football players. No significant difference was found in the comparison of hand



**Figure 1.** Light Trainer Pro system.

visual response times for volleyball players before and after the warm-up ( $Z = -1.561, p = 0.119$ ). However, a significant difference was found in the comparison of hand visual response times for football players before and after the warm-up ( $t = 2.887, p = 0.016$ ). No significant difference was observed when comparing the hand visual response times of volleyball and football players both before ( $t = 1.905, p = 0.071$ ) and after the warm-up ( $U = 43.000, p = 0.247$ ).

Figure 3 presents the foot visual response times of the participants. A significant difference was found in the comparison of volleyball players' foot visual response times before and after the warm-up ( $Z = -2.674, p = 0.007$ ). No significant difference was observed in the comparison of football players' foot visual response times before and after the warm-up ( $t = 2.132, p = 0.059$ ). A significant difference was determined when comparing the foot visual response times of volleyball and football players

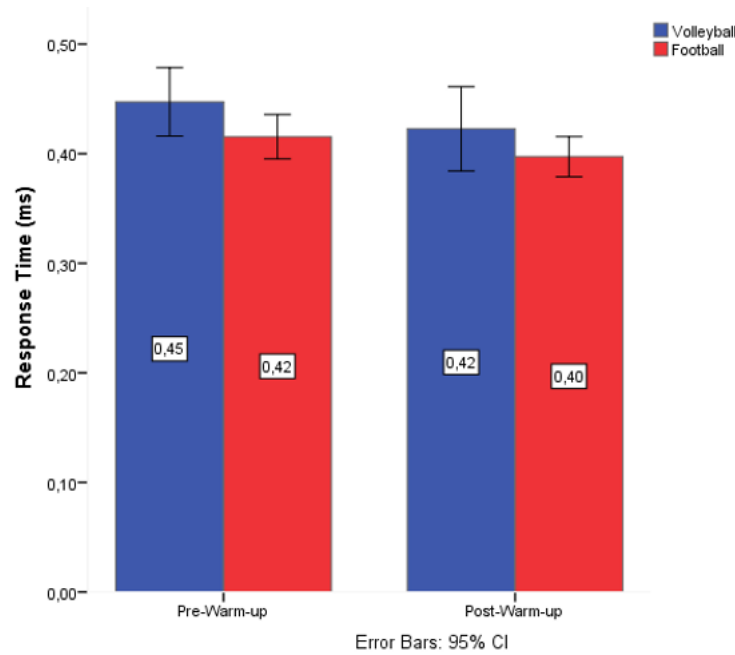


Figure 2. Hand visual response times.

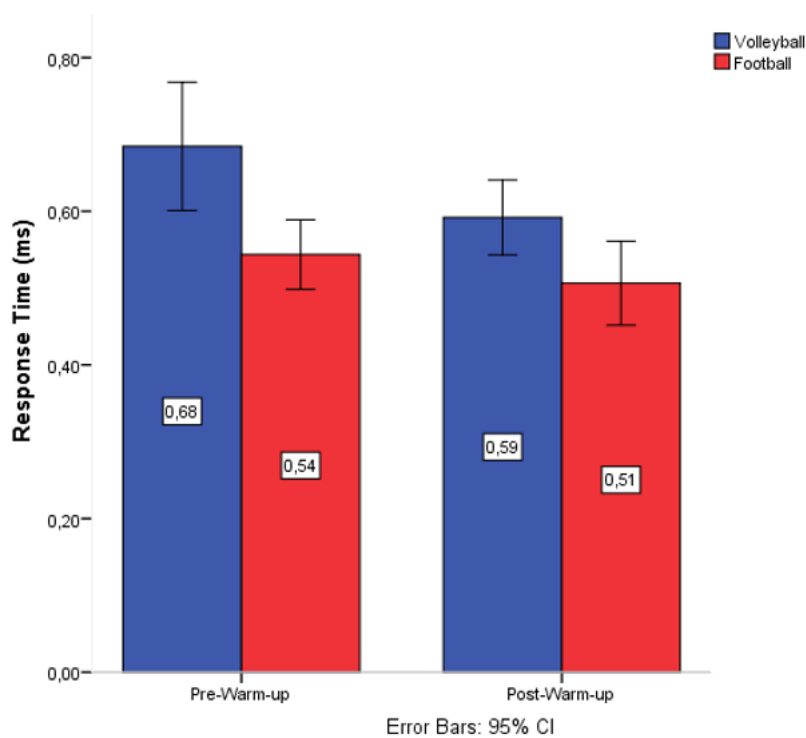


Figure 3. Foot visual response times.

both before ( $t = 3.307$ ,  $p = 0.004$ ) and after the warm-up ( $U = 20.000$ ,  $p = 0.008$ ). This difference indicated that volleyball players had a greater decrease in visual response time than football players after the warm-up.

## Discussion

The aim of this study was to investigate the effects of sport-specific warm-up activities on the hand and foot visual response times of female athletes. The results revealed no significant difference in the hand visual response times between volleyball and football players after the warm-up. Volleyball players' hand response times did not change before or after the warm-up. However, football players showed significantly faster response times after the warm-up compared to before. This result suggests that football players experienced a greater improvement in their visual responses following the sport-specific warm-up. There was a significant change in foot visual response times after the branch-specific warm-up. It was found that volleyball players' foot visual response times improved more than those of football players after the warm-up. However, football players had faster response times both before and after the warm-up. This suggests that the warm-up activities specific to volleyball are more effective than those for football in improving foot visual response times. It has been noted that athletes' dominant limbs (e.g., hand or foot) tend to show less improvement in response times after the warm-up compared to their less dominant limbs, due to the nature of the sport. This may suggest that the frequently used limbs of athletes are already close to their optimal performance level in terms of response time.

It has been noted that response time, which positively affects performance, is faster in athletes with similar technical and fitness levels, and athletes with shorter response times tend to develop more quickly. Moreover, this effect is even more significant across different sports disciplines. During training and competition, an athlete who executes movements faster than their opponent gains a competitive advantage. This is supported by the results of the study by Kockum et al. [18], where the authors note that elite-level athletes typically have shorter response times compared to amateur-level athletes.

According to the findings of the study, no difference was observed in the hand visual response times of volleyball and football players after the sport-specific warm-up compared to pre-warm-up. However, football players showed a significant improvement in visual response time after the warm-up. Some studies have examined the effects of warm-up activities on various parameters. In one such study, it was reported that a 25-minute warm-up had no significant effect on the visual response

times of the dominant and non-dominant hands of basketball players. This result suggests that warm-up activities may not lead to a significant improvement in visual response times or may not cause notable differences in response times between players [19].

In another study, the effect of warm-up activity on upper extremity (hand) reaction time was examined, and it was reported that warm-up activity did not significantly affect reaction time [20]. These findings are consistent with our study and suggest that the effects of sport-specific warm-up activities on visual response time may be limited. However, in contrast to our study, a different investigation examined the reaction times of participants from seven different sports (football, volleyball, handball, boxing, arm wrestling, basketball, and rugby), including football and volleyball players, and found differences in visual reaction times between the branches [21].

In another study [14], it was found that a warm-up involving core exercises and elastic bands had a greater impact on sprint time, jump height, medicine ball throwing speed, and handball throwing performance compared to a traditional warm-up, as well as core and elastic band warm-up activities. In the literature, studies investigating the effects of sport-specific warm-up activities on the visual reaction time of female athletes are limited. Existing research examines warm-ups across different sports and under various parameters. Therefore, this study makes a unique contribution to the literature by focusing on female athletes and incorporating branch-specific warm-up activities.

In sports where competition is highly important, lower extremity (foot) performance parameters are equally critical. The lower extremities play a key role in an athlete's performance, enabling fundamental movements such as running, changing direction, and jumping [22]. Therefore, just as with the upper extremities, it is essential for athletes to demonstrate quick response times, which is a key performance parameter, in their lower extremities as well.

According to the findings of the study, volleyball players showed greater improvement in response times than football players after the branch-specific warm-up activity. However, football players had better foot response times than volleyball players both before and after the warm-up. This suggests that football players may naturally have faster response times or may have developed this skill more effectively due to the demands of their sport. In a study supporting our findings, reaction times across three different sports (football, volleyball, and wrestling) were compared, and it was reported that football players had shorter reaction times than both volleyball and wrestling players [23]. However, some studies have reported that warm-up activities did not affect the reaction times of the lower extremities (foot) [19, 24].

In contrast to these findings, our study showed a significant improvement in foot visual response times for volleyball players after the sport-specific warm-up. However, similar to previous studies, the foot response times of football players did not show a significant change after the warm-up. These results suggest that the effectiveness of warm-up activities may vary depending on the specific demands of each sport and the limbs predominantly used by the athletes. Furthermore, the improvements in volleyball players' foot response times may indicate that sport-specific warm-ups are more beneficial for certain types of movements and muscle groups.

In conclusion, this study demonstrated that sport-specific warm-up activities have varying effects on visual response times in female athletes, depending on the sport and the extremity involved. Volleyball players showed greater improvements in foot visual response times after the warm-up, while football players exhibited faster baseline response times but did not significantly benefit from the warm-up. These findings highlight the importance of tailoring warm-up protocols to the specific demands of each sport. However, the study has some limitations, including the relatively small sample size and the focus on only two sports. Additionally, the study

did not account for potential individual differences in physical conditioning or prior warm-up habits. Future research should explore a broader range of sports and include a larger, more diverse group of athletes to better understand the generalizability of these results.

## Conclusions

The results show that the effects of branch-specific warm-up activities on hand and foot response times differed between football and volleyball players. Football players outperformed volleyball players in both hand and foot response times. However, a significant improvement in foot response times was observed in volleyball players after the sport-specific warm-up, while football players maintained overall faster response times after the warm-up. These findings suggest that the specific demands of each sport and the warm-up activities may influence athletes' response times in different ways.

This study was presented as an oral presentation at the VII INCES International Science, Culture and Education Congress, held from April 28 to May 1, 2024.

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Cite this article as:

Gögebakan R, Baştürk D, Arguz A, Bayraktar Y, Erkmen N, Say S. The effect of sports specific warm-up on lower and upper extremity visual response time in female athletes. *Physical Education of Students*, 2024;28(5):296–302. <https://doi.org/10.15561/20755279.2024.0506>

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Received: 02.09.2024

Accepted: 06.10.2024; Published: 30.10.2024

# Reliability and objectivity of the new version of the ‘susceptibility test for body injuries during a fall’ (STBIDF-M) in physiotherapy students

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

## Abstract

**Background and Study Aim** Falls are a global public health and economic challenge. Since falls are often unavoidable, it is crucial to focus on preventing injuries caused by the impact with the ground. The aim of this study was to verify the reliability and objectivity of the STBIDF-M.

**Material and Methods** The sample included 30 male (n = 9) and female (n = 21) physiotherapy students (age  $20.97 \pm 1.16$  years; weight:  $66.5 \pm 12.06$  kg; height:  $171 \pm 9.62$  cm). The STBIDF-M was administered twice, with the second measurement (retest) conducted seven days after the first (test). A method of direct secondary observation, allowing for multiple replays, was used. The assessment involved reviewing video recordings of both stages (test and retest) by three experts experienced in using the STBIDF-M.

**Results** Each expert observed a tendency to reduce errors during the ‘retest’ compared to the ‘test’ stage. This was measured by the arithmetic mean. Statistically significant differences were found in tasks 3, 4, 5, 6, and in the IndexSBIDF-M based on the experts’ agreed assessments. Three students (10%) repeated their results from the ‘test’ stage, showing full correlation. Twenty students (66.67%) demonstrated a tendency to reduce errors. The IndexSBIDF-M ‘test-retest’ results showed a very high positive correlation ( $r = 0.810$ ,  $p < 0.01$ ). This indicates a statistically significant impact of motor modifications in most students. Specifically, clapping hands during Task 3 and pressing the sponge to the body with the chin during Task 4, simulating a backward fall, helped reduce errors. These reductions were noted during ground impact as the degree of coordination difficulty increased in subsequent tasks.

**Conclusions** The results of this ‘test-retest’ procedure demonstrate the flexible, non-standardized possibilities of analyzing and synthesizing data using this basic method. This flexibility is attributed to the innovative motor structure of the STBIDF-M, which goes beyond traditional methodological approaches. Observing the unconscious behaviors and actions of the participants has provided valuable insights into inferential phenomena related to the mental and intellectual aspects of human personality.

**Keywords:** complementary approach, INNOAGON, simulated fall backwards, unintentional fall

## Introduction

Falls are a global health and economic concern. They affect people of all ages. The epidemiology of falls, excluding groups at increased risk, is influenced by climatic conditions and the structure of the ground, including infrastructure. The lowest rates of years lived with a disability and years lost to premature death due to falls are reported in Africa, while the highest rates are found in Scandinavian and other European countries [1]. Most prevention recommendations focus on reducing the risk of falls, particularly among older adults. However, the effectiveness of such interventions impacts only ...% of participants [2].

Since a fall is inevitable, it is fundamental to prevent injury from the impact caused by a fall. The

most effective method is to master safe falling skills (techniques) [3]. With an ageing population, it makes little sense to universally teach safe falling to people over 60. Therefore, attention has been drawn to the unique research results and expert recommendations of the ‘Polish School of Safe Falling’ [4] regarding the phenomenon of susceptibility to body injuries during a fall (SFI) [5]. A key contribution is the development of tools to diagnose the SFI phenomenon, along with secondary intervention programs tailored to individual profiles. The large inter-individual variation and complexity of the SFI phenomenon has been revealed by unique tools (non-apparatus tests) from the new applied science of ‘innovative agonology’ – INNOAGON [6, 7].

Conclusions from the analysis of the results of many previous studies using the susceptibility test for body injuries during a fall (STBIDF) [8] show that the creator of this first tool was inspired by

the 'safe falling' theory by Jaskólski and Nowacki in 1972 [9]. This theory was later expanded by Mroczkowski [10]. In 2011, the first results of the STBIDF validation procedure were published [11], and data on its reliability ('test-retest' score) became available in 2022 [12]. In 2023, a comprehensive publication on the prognostic merits of the STBIDF was released [13]. The authors of this publication, while observing a large sample of physiotherapy and physical education students, discovered that the majority had previously experienced traumatic injuries as a result of a fall. The analysis and synthesis of the results from this group revealed the high predictive power of the STBIDF and introduced a new methodological perspective for using this category of tools to explore the SFI phenomenon.

The STBIDF [14, 15, 16, 17] showed that a single evaluation of the lower limbs (referred to as 'legs' in the documentation) is insufficient [18, 19, 20, 21]. A modification of the STBIDF-M (susceptibility test for body injuries during a fall – modified) includes a three-fold evaluation of the legs on a three-point scale indicating error or absence (0, 1, 2). This modification is the result of expanding the test version from three to six tasks [22, 23, 24, 25]. Each body part is evaluated at least three times. The validation procedure for this modification has been limited to an assessment of validity [5, 26, 27].

Thus, previous studies have contributed valuable insights into the evaluation of susceptibility to injuries during falls and the development of tools like the STBIDF and its modified version, STBIDF-M. However, the analysis of the studies highlights limitations in their validation, particularly regarding reliability and objectivity. Moreover, the variability in individual responses to falls and the complexity of injury susceptibility necessitates the search for new, more effective solutions.

The aim of the study was to verify the reliability and objectivity of the STBIDF-M.

## Material and Methods

### *Participants*

The sample included 30 male ( $n = 9$ ) and female ( $n = 21$ ) physiotherapy students (age:  $20.97 \pm 1.16$  years; weight:  $66.5 \pm 12.06$  kg; height:  $171 \pm 9.62$  cm). The participants were selected from a pool of 41 students enrolled in their first-degree studies during the fifth semester. The inclusion criteria were an adequate health state and voluntary participation. Exclusion criteria included a lack of consent to participate, pregnancy, and any dysfunctions that would prevent taking the test. All participants were thoroughly informed about the aim of the study prior to their participation.

### *Study Design*

#### *Assessment of the susceptibility to body injuries*

#### *during a fall*

The STBIDF-M was administered [5]. Each student was recorded while performing the test, with the camcorder capturing the required motor activities in the sagittal plane. Participants waiting for their turn were kept in a separate room, with no contact allowed between those who had completed the test and those yet to perform it.

The structure of the STBIDF-M consisted of six motor tasks performed on tatami mats. The assessment focused on protecting body parts most vulnerable to injury during a fall (head, hands, hips, legs). Any incorrect collision during the fastest possible transition from a vertical (standing) to a horizontal (lying on the back) position was recorded as either a first-grade ("1") or second-grade ("2") error, with no errors marked as "0." The total score served as a general indicator of susceptibility to body injuries during a fall (i.e., the  $\text{Index}_{\text{SBIDF-M}}$ ). The scores were classified as very low (0), low (1–11), average (12–18), high (19–23), very high (24–27), and extreme (28–30). For individual body parts, the scores were:

- Legs, hips, head: very low (0), low (1), average (2–3), high (4), very high (5), and extreme (6).
- Hands: very low (0), low (1–2), average (4–6), high (7–8), very high (9–10), and extreme (11–12).

#### *Assessment of the reliability of the STBIDF using a test-retest approach*

The test was conducted twice. The second measurement (retest) took place seven days after the initial test. Each participant performed both the test and retest individually. Both sessions were carried out at the same time of day, in the same room, and using identical procedures.

#### *Assessment of the objectivity of the STBIDF using the Delphi method (expert panel)*

The method of direct secondary observation with the possibility of multiple replays was applied. The assessment procedure involved reviewing video recordings of both stages of the study (test and retest) by three experts experienced in using the STBIDF-M. Initially, the experts independently evaluated the recordings without sharing their assessments. In cases of scoring discrepancies, the experts reviewed the recordings together (multiple times if necessary) and discussed their opinions before reaching a consensus on the final result.

#### *Statistical analysis*

Differences between the test and retest scores were analyzed using the Wilcoxon signed-rank test and T-Test for two dependent means, with the alpha level set at  $<0.05$ . Spearman's rank correlation coefficient ( $r$ ) was employed to assess the relationships between variables. Arithmetic means ( $\bar{x}$ ), standard deviations (SD or  $\pm$ ), minimum (Min),

maximum (Max) scores, degrees of freedom (df), skewness (g1), and kurtosis (g2) were calculated, along with z-distribution (z) and probability (p).

To further explore the distribution of differences between the 'test' and 'retest' stages, ranking positions (RP) were assigned based on performance indicators. In cases of equal values, the higher RP was allocated to the participant with the higher 'test' stage score. When multiple participants had identical results, additional identifiers, such as lower-case letters after the RP, were introduced to distinguish them. This classification allowed for dividing participants into different fractions based on their performance trends: error-reducing, stable, or error-augmenting.

## Results

The results showed that each of the experts observed a trend of reducing errors during the 'retest' stage in relation to the score of each task from the 'test' stage, as measured by the arithmetic mean (Table 1). This trend is supported by statistically significant differences in the scores of tasks 3, 4, 5, 6, and the  $Index_{SBIDF-M}$  based on the experts' consensus scores (Table 2). Additionally, statistically significant correlations of the agreed scores for the nondirectional test were found only from Task 3 onwards. However, the level of generality of the 'test-retest' scores presented

in Tables 2 and 3 does not account for individual differences.

Tables 3-5 present the evaluation of the STBIDF-M task scores for physiotherapy students during the 'test-retest' procedure, divided into three distinct groups. The classification divides students into three groups: Table 3 shows the stable fraction, Table 4 presents the error-reducing fraction, and Table 5 highlights the error-augmenting fraction.

The data in Table 3 demonstrate that three students (10%) repeated the score from the 'test' stage, indicating a full score correlation. The data in Table 4 demonstrate that twenty students (66.67%) revealed a tendency to reduce errors. The  $Index_{SBIDF-M}$  'test-retest' scores correlate very highly and positively ( $r = 0.810$ ,  $p < 0.01$ ). This provides statistically significant evidence of motor modifications reducing errors during ground impact in Task 2 of the simulated backward fall. The finding is particularly important, as the positive effect occurs despite the increasing coordination difficulty of Task 2 and each subsequent task. The data in Table 5 demonstrate that seven students (23.33%) revealed a tendency to magnify errors. However, the positive correlation of repeated observations with 'test' scores ( $r = 0.661$ ) is not statistically significant, although it is borderline for directional test significance at df 5.

A statistically significant reduction in head-on

**Table 1.** Estimation of overall task scores (total points) of STBIDF-M ('test-retest') assessment by three independent experts (A, B, C).

| Estimation      | STBIDF-M result (points) – possible results of odd Tasks (shaded grey from 0 to 4 points) & even Tasks (without shade 0 to 6) |        |      |        |      |        |      |        |      |        |      |        | $Index_{SBIDF-M}$ (points) |        |
|-----------------|---|--------|------|--------|------|--------|------|--------|------|--------|------|--------|----------------------------|--------|
|                 | 1   |        | 2    |        | 3    |        | 4    |        | 5    |        | 6    |        |                            |        |
|                 | test  | retest | test | retest | test | retest | test | retest | test | retest | test | retest | test                       | retest |
| <b>Expert A</b> |   |        |      |        |      |        |      |        |      |        |      |        |                            |        |
| $\bar{X}$       | 2.43  | 2.27   | 2.67 | 2.53   | 1.93 | 1.77   | 2.37 | 1.80   | 2.00 | 1.73   | 2.57 | 2.13   | 13.97                      | 12.23  |
| SD              | 0.97  | 1.23   | 0.99 | 1.14   | 1.11 | 1.10   | 1.00 | 1.19   | 0.87 | 0.83   | 0.97 | 0.97   | 4.29                       | 5.59   |
| Min             | 1   | 0      | 1    | 0      | 0    | 0      | 0    | 0      | 0    | 0      | 0    | 0      | 4                          | 0      |
| Max             | 4   | 4      | 4    | 4      | 4    | 3      | 4    | 4      | 3    | 3      | 4    | 4      | 20                         | 18     |
| <b>Expert B</b> |   |        |      |        |      |        |      |        |      |        |      |        |                            |        |
| $\bar{X}$       | 2.43  | 2.2    | 2.7  | 2.47   | 1.97 | 1.8    | 2.4  | 1.87   | 2    | 1.73   | 2.6  | 2.2    | 14.1                       | 12.27  |
| SD              | 0.94  | 1.16   | 0.95 | 1.14   | 0.93 | 1.10   | 1.04 | 1.28   | 0.83 | 0.78   | 0.89 | 1.06   | 4.04                       | 5.64   |
| Min             | 1   | 0      | 1    | 0      | 0    | 0      | 0    | 0      | 0    | 0      | 0    | 0      | 4                          | 0      |
| Max             | 4   | 3      | 4    | 4      | 3    | 3      | 4    | 4      | 3    | 3      | 4    | 4      | 20                         | 20     |
| <b>Expert C</b> |   |        |      |        |      |        |      |        |      |        |      |        |                            |        |
| $\bar{X}$       | 2.43  | 2.2    | 2.8  | 2.47   | 1.93 | 1.83   | 2.43 | 1.9    | 2.07 | 1.77   | 2.63 | 2.2    | 14.3                       | 12.37  |
| SD              | 0.94  | 1.16   | 1.10 | 1.14   | 0.98 | 1.12   | 1.07 | 1.30   | 0.83 | 0.77   | 1.03 | 1.06   | 4.29                       | 5.70   |
| Min             | 1   | 0      | 1    | 0      | 0    | 0      | 0    | 0      | 0    | 0      | 0    | 0      | 4                          | 0      |
| Max             | 4   | 3      | 5    | 4      | 3    | 3      | 4    | 4      | 3    | 3      | 5    | 4      | 20                         | 20     |

**Table 2.** Estimation of overall task scores (total points) of STBIDF-M ('test-retest') after all experts corrections.

| Estimation                | STBIDF-M result (points) – possible results of odd Tasks (shaded grey from 0 to 4 points) & even Tasks (without shade 0 to 6) |        |                           |        |                           |        |   |        |   |        |   |        | Index <sub>SBIDF-M</sub> (points)         |        |
|---------------------------|---|--------|---------------------------|--------|---------------------------|--------|---|--------|---|--------|---|--------|---|--------|
|                           | 1   |        | 2                         |        | 3                         |        | 4   |        | 5   |        | 6   |        |   |        |
|                           | test  | retest | test                      | retest | test                      | retest | test                                      | retest | test                                      | retest | test                                      | retest | test                                      | retest |
| $\bar{x}$                 | 2.43  | 2.23   | 2.8                       | 2.47   | 1.93                      | 1.77   | 2.4                                       | 1.87   | 2.03                                      | 1.73   | 2.63                                      | 2.2    | 14.23                                     | 12.27  |
| SD                        | 0.94  | 1.19   | 1.10                      | 1.14   | 0.98                      | 1.07   | 1.04                                      | 1.28   | 0.85                                      | 0.78   | 1.03                                      | 1.06   | 4.22                                      | 5.67   |
| Min                       | 1   | 0      | 1                         | 0      | 0                         | 0      | 0   | 0      | 0   | 0      | 0   | 0      | 4   | 0      |
| Max                       | 4   | 4      | 5                         | 4      | 3                         | 3      | 4   | 4      | 3   | 3      | 5   | 4      | 20  | 20     |
| g1                        | -0.74   | -0.87  | -0.08                     | -0.74  | -0.57                     | -0.40  | -0.31                                     | -0.05  | -0.43                                     | 0.07   | -0.18                                     | -0.06  | -0.54                                     | -0.56  |
| g2                        | -1.02   | -0.69  | -0.12                     | -0.27  | -0.61                     | -1.04  | -0.40                                     | -0.97  | -0.59                                     | -0.53  | 0.74                                      | -0.83  | -0.67                                     | -0.81  |
| Spearman rank correlation | 0.085   |        | <b>0.319<sup>*^</sup></b> |        | <b>0.526<sup>**</sup></b> |        | <b>0.519<sup>**</sup></b>                 |        | <b>0.651<sup>***</sup></b>                |        | <b>0.571<sup>***</sup></b>                |        | <b>0.494<sup>**</sup></b>                 |        |
| Wilcoxon Signed-Rank Test | Z = 0.566<br>p = 0.568  |        | Z = 1.432<br>p = 0.152    |        | Z = -0.847<br>p = 0.395   |        | Z = 2.295<br>p = <b>0.021<sup>*</sup></b> |        | Z = 2.118<br>p = <b>0.034<sup>*</sup></b> |        | Z = 2.106<br>p = <b>0.035<sup>*</sup></b> |        | Z = 1.982<br>p = <b>0.047<sup>*</sup></b> |        |

\*p<0.05; \*\*p<0.01; \*\*\*p<0.001; ^one-sided test

**Table 3.** Estimation of the scores (total points) of the STBIDF-M tasks of three physiotherapy students who repeated errors (identical Index<sub>SBIDF-M</sub>) during the 'test-retest' procedure - 'stable' fraction (S).

| Code/RP   | Tasks of the 'test' stage |      |      |      |      |      |           | Index <sub>SBIDF-M</sub> | Tasks of the 'retest' stage |      |      |      |      |           |  | Index <sub>SBIDF-M</sub> |
|-----------|---------------------------|------|------|------|------|------|-----------|--------------------------|-----------------------------|------|------|------|------|-----------|--|--------------------------|
|           | 1                         | 2    | 3    | 4    | 5    | 6    | 1         |                          | 2                           | 3    | 4    | 5    | 6    |           |  |                          |
| S1a       | 3                         | 3    | 3    | 3    | 3    | 3    | <b>18</b> | 3                        | 3                           | 3    | 3    | 3    | 3    | <b>18</b> |  |                          |
| S1b       | 3                         | 3    | 3    | 3    | 3    | 3    | <b>18</b> | 3                        | 3                           | 3    | 3    | 3    | 3    | <b>18</b> |  |                          |
| S2        | 1                         | 1    | 1    | 1    | 2    | 2    | <b>8</b>  | 1                        | 1                           | 1    | 1    | 2    | 2    | <b>8</b>  |  |                          |
| $\bar{x}$ | 2.33                      | 2.33 | 2.33 | 2.33 | 2.67 | 2.67 | 14.67     | 2.33                     | 2.33                        | 2.33 | 2.33 | 2.67 | 2.67 | 14.67     |  |                          |
| SD        | 1.15                      | 1.15 | 1.15 | 1.15 | 0.58 | 0.58 | 5.77      | 1.15                     | 1.15                        | 1.15 | 1.15 | 0.58 | 0.58 | 5.77      |  |                          |
| Min       | 1                         | 1    | 1    | 1    | 2    | 2    | 8         | 1                        | 1                           | 1    | 1    | 2    | 2    | 8         |  |                          |
| Max       | 3                         | 3    | 3    | 3    | 3    | 3    | 18        | 3                        | 3                           | 3    | 3    | 3    | 3    | 18        |  |                          |

**Table 4.** Estimation of the scores (total points) of the STBIDF-M tasks of the twenty physiotherapy students who reduced errors during the 'retest' stage – the 'error-reducing' fraction (R).

| Code/RP  | Tasks of the 'test' stage |          |          |          |          |          |           | Index <sub>SBIDF-M</sub> | Tasks of the 'retest' stage |           |           |           |           |                          |           | Difference (-) |
|----------|---------------------------|----------|----------|----------|----------|----------|-----------|--------------------------|-----------------------------|-----------|-----------|-----------|-----------|--------------------------|-----------|----------------|
|          | 1                         | 2        | 3        | 4        | 5        | 6        | 1         |                          | 2                           | 3         | 4         | 5         | 6         | Index <sub>SBIDF-M</sub> |           |                |
| <b>1</b> | <b>2</b>                  | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b>  | <b>9</b>                 | <b>10</b>                   | <b>11</b> | <b>12</b> | <b>13</b> | <b>14</b> | <b>15</b>                | <b>16</b> |                |
| R1       | 2                         | 3        | 3        | 3        | 3        | 2        | <b>16</b> | 1                        | 1                           | 1         | 0         | 1         | 1         | <b>5</b>                 | 11        |                |
| R2a      | 3                         | 5        | 2        | 3        | 2        | 4        | <b>19</b> | 1                        | 3                           | 1         | 1         | 1         | 2         | <b>9</b>                 | 10        |                |
| R2b      | 3                         | 4        | 2        | 3        | 2        | 2        | <b>16</b> | 1                        | 1                           | 1         | 1         | 1         | 1         | <b>6</b>                 | 10        |                |
| R3       | 2                         | 2        | 2        | 2        | 1        | 1        | <b>10</b> | 0                        | 0                           | 0         | 0         | 1         | 1         | <b>2</b>                 | 8         |                |
| R4       | 3                         | 1        | 1        | 1        | 2        | 2        | <b>10</b> | 1                        | 1                           | 0         | 0         | 1         | 1         | <b>4</b>                 | 6         |                |
| R5a      | 1                         | 5        | 2        | 4        | 1        | 5        | <b>18</b> | 3                        | 2                           | 3         | 2         | 2         | 1         | <b>13</b>                | 5         |                |

**Table 4.** Continued

| 1         | 2     | 3    | 4     | 5     | 6     | 7    | 8         | 9     | 10    | 11    | 12    | 13   | 14    | 15        | 16    |
|-----------|-------|------|-------|-------|-------|------|-----------|-------|-------|-------|-------|------|-------|-----------|-------|
| R5b       | 3     | 4    | 3     | 4     | 2     | 2    | <b>18</b> | 3     | 4     | 1     | 2     | 1    | 2     | <b>13</b> | 5     |
| R5c       | 3     | 4    | 2     | 3     | 2     | 3    | <b>17</b> | 3     | 1     | 2     | 3     | 1    | 2     | <b>12</b> | 5     |
| R5d       | 3     | 2    | 0     | 2     | 1     | 3    | <b>11</b> | 0     | 2     | 0     | 1     | 1    | 2     | <b>6</b>  | 5     |
| R5e       | 3     | 3    | 0     | 1     | 1     | 2    | <b>10</b> | 0     | 3     | 0     | 0     | 1    | 1     | <b>5</b>  | 5     |
| R6a       | 3     | 3    | 3     | 4     | 3     | 3    | <b>19</b> | 3     | 3     | 3     | 2     | 2    | 2     | <b>15</b> | 4     |
| R6b       | 1     | 1    | 1     | 1     | 0     | 0    | <b>4</b>  | 0     | 0     | 0     | 0     | 0    | 0     | <b>0</b>  | 4     |
| R7        | 3     | 3    | 3     | 3     | 3     | 3    | <b>18</b> | 3     | 3     | 2     | 2     | 2    | 3     | <b>15</b> | 3     |
| R8a       | 3     | 3    | 3     | 4     | 3     | 4    | <b>20</b> | 3     | 3     | 3     | 3     | 3    | 3     | <b>18</b> | 2     |
| R8b       | 3     | 3    | 1     | 2     | 1     | 2    | <b>12</b> | 2     | 2     | 2     | 2     | 1    | 1     | <b>10</b> | 2     |
| R9a       | 4     | 3    | 3     | 3     | 3     | 3    | <b>19</b> | 3     | 3     | 3     | 3     | 3    | 3     | <b>18</b> | 1     |
| R9b       | 3     | 3    | 3     | 3     | 3     | 3    | <b>18</b> | 3     | 3     | 3     | 3     | 2    | 3     | <b>17</b> | 1     |
| R9c       | 3     | 3    | 3     | 2     | 2     | 2    | <b>15</b> | 3     | 3     | 2     | 2     | 2    | 2     | <b>14</b> | 1     |
| R9d       | 3     | 3    | 2     | 2     | 2     | 3    | <b>15</b> | 3     | 3     | 2     | 2     | 2    | 2     | <b>14</b> | 1     |
| R9e       | 3     | 2    | 2     | 0     | 1     | 1    | <b>9</b>  | 2     | 2     | 2     | 0     | 1    | 1     | <b>8</b>  | 1     |
| $\bar{x}$ | 2.75  | 3    | 2.05  | 2.5   | 1.9   | 2.5  | 14.7      | 1.9   | 2.15  | 1.55  | 1.45  | 1.45 | 1.7   | 10.2      | 4.5   |
| SD        | 0.72  | 1.08 | 1.00  | 1.15  | 0.91  | 1.15 | 4.41      | 1.25  | 1.14  | 1.15  | 1.15  | 0.76 | 0.86  | 5.46      | 3.20  |
| Min       | 1     | 1    | 0     | 0     | 0     | 0    | 4         | 0     | 0     | 0     | 0     | 0    | 0     | 0         | 1     |
| Max       | 4     | 5    | 3     | 4     | 3     | 5    | 20        | 3     | 4     | 3     | 3     | 3    | 3     | 18        | 11    |
| g1        | -1.49 | 0.00 | -0.81 | -0.46 | -0.25 | 0.00 | -0.85     | -0.51 | -0.56 | -0.14 | -0.10 | 0.59 | 0.12  | -0.23     | 0.72  |
| g2        | 2.47  | 0.23 | -0.24 | -0.40 | -0.85 | 0.60 | -0.08     | -1.50 | -0.68 | -1.38 | -1.43 | 0.15 | -0.73 | -1.10     | -0.38 |

**Table 5.** Estimation of the scores (total points) of the STBIDF-M tasks of the seven physiotherapy students who magnified errors during the ‘retest’ stage - the ‘error magnifying’ fraction (M).

| Code/<br>RP | Tasks of the ‘test’ stage |      |      |      |      |      |                          | Tasks of the ‘retest’ stage |      |      |      |      |      |                          | Difference (+) |
|-------------|---------------------------|------|------|------|------|------|--------------------------|-----------------------------|------|------|------|------|------|--------------------------|----------------|
|             | 1                         | 2    | 3    | 4    | 5    | 6    | Index <sub>SBIDF-M</sub> | 1                           | 2    | 3    | 4    | 5    | 6    | Index <sub>SBIDF-M</sub> |                |
| M1          | 1                         | 3    | 2    | 2    | 2    | 3    | <b>13</b>                | 3                           | 4    | 3    | 4    | 2    | 4    | <b>20</b>                | 7              |
| M2a         | 1                         | 1    | 1    | 3    | 3    | 3    | <b>12</b>                | 3                           | 3    | 1    | 4    | 3    | 4    | <b>18</b>                | 6              |
| M2b         | 1                         | 3    | 0    | 2    | 1    | 2    | <b>9</b>                 | 3                           | 3    | 2    | 2    | 2    | 3    | <b>15</b>                | 6              |
| M2c         | 1                         | 1    | 1    | 1    | 2    | 3    | <b>9</b>                 | 3                           | 3    | 3    | 1    | 2    | 3    | <b>15</b>                | 6              |
| M3          | 3                         | 3    | 2    | 2    | 2    | 2    | <b>14</b>                | 3                           | 4    | 2    | 3    | 2    | 3    | <b>17</b>                | 3              |
| M4          | 3                         | 4    | 2    | 3    | 2    | 4    | <b>18</b>                | 4                           | 4    | 2    | 4    | 2    | 4    | <b>20</b>                | 2              |
| M5          | 1                         | 2    | 2    | 2    | 3    | 4    | <b>14</b>                | 3                           | 3    | 2    | 2    | 2    | 3    | <b>15</b>                | 1              |
| $\bar{x}$   | 1.57                      | 2.43 | 1.43 | 2.14 | 2.14 | 3    | 12.71                    | 3.14                        | 3.43 | 2.14 | 2.86 | 2.14 | 3.43 | 17.14                    | 4.43           |
| SD          | 0.98                      | 1.13 | 0.79 | 0.69 | 0.69 | 0.82 | 3.15                     | 0.38                        | 0.53 | 0.69 | 1.21 | 0.38 | 0.53 | 2.27                     | 2.37           |
| Min         | 1                         | 1    | 0    | 1    | 1    | 2    | 9                        | 3                           | 3    | 1    | 1    | 2    | 3    | 15                       | 1              |
| Max         | 3                         | 4    | 2    | 3    | 3    | 4    | 18                       | 4                           | 4    | 3    | 4    | 3    | 4    | 20                       | 7              |

collision errors during a simulated fall was observed by all experts. This provides important empirical evidence. The sponge motor modification is shown to be a highly effective methodological innovation (Table 6).

## Discussion

The aim of this study was to verify the reliability and objectivity of the modified susceptibility test for body injuries during a fall (STBIDF-M). The results demonstrated a statistically significant reduction in

**Table 6.** Mean score and SD corresponding to the susceptibility of the predetermined parts of the body to injuries in physiotherapy students (n = 30).

| Body parts in STBIDF-M tasks (points) |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |  |
|---------------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--|
| Stage                                 | Task 1        |               |               | Task 2        |               |               | Task 3        |               |               | Task 4        |               |               | Task 5        |               |               | Task 6        |               |               |               |               |               |  |
|                                       | hips          | arms          | head          | legs          | hips          | arms          | head          | hips          | arms          | head          | legs          | hips          | arms          | head          | hips          | arms          | head          | legs          | hips          | arms          | head          |  |
| <b>Expert A</b>                       |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |  |
| Test                                  | 0.07<br>±0.25 | 1.43<br>±0.9  | 0.93<br>±0.25 | 0.17<br>±0.38 | 0.03<br>±0.18 | 1.57<br>±0.82 | 0.9<br>±0.31  | 0.03<br>±0.18 | 1.3<br>±0.88  | 0.6<br>±0.5   | 0.3<br>±0.47  | 0.03<br>±0.18 | 1.4<br>±0.86  | 0.63<br>±0.49 | 0.03<br>±0.18 | 1.33<br>±0.61 | 0.63<br>±0.49 | 0.3<br>±0.53  | 0.07<br>±0.25 | 1.47<br>±0.57 | 0.73<br>±0.45 |  |
| Retest                                | 0.13<br>±0.35 | 1.33<br>±0.92 | 0.8<br>±0.41  | 0.23<br>±0.43 | 0.03<br>±0.18 | 1.43<br>±0.86 | 0.83<br>±0.38 | 0.07<br>±0.25 | 1.13<br>±0.94 | 0.57<br>±0.5  | 0.23<br>±0.43 | 0.03<br>±0.18 | 1.07<br>±0.94 | 0.47<br>±0.51 | 0.07<br>±0.25 | 1.27<br>±0.69 | 0.4<br>±0.5   | 0.3<br>±0.47  | 0.03<br>±0.18 | 1.3<br>±0.65  | 0.5<br>±0.51  |  |
| Difference                            | 0.07          | 0.1           | 0.13          | 0.07          | 0             | 0.13          | 0.07          | 0.03          | 0.17          | 0.03          | 0.07          | 0             | 0.33*         | 0.17          | 0.03          | 0.07          | 0.23*         | 0             | 0.03          | 0.17          | 0.23*         |  |
| <b>Expert B</b>                       |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |  |
| Test                                  | 0.03<br>±0.18 | 1.47<br>±0.9  | 0.93<br>±0.25 | 0.2<br>±0.41  | 0.03<br>±0.18 | 1.57<br>±0.82 | 0.9<br>±0.31  | 0.03<br>±0.18 | 1.3<br>±0.88  | 0.63<br>±0.56 | 0.3<br>±0.47  | 0.03<br>±0.18 | 1.4<br>±0.86  | 0.67<br>±0.48 | 0.03<br>±0.18 | 1.33<br>±0.55 | 0.63<br>±0.49 | 0.3<br>±0.53  | 0.03<br>±0.18 | 1.5<br>±0.57  | 0.77<br>±0.43 |  |
| Retest                                | 0.07<br>±0.25 | 1.33<br>±0.92 | 0.8<br>±0.41  | 0.2<br>±0.41  | 0.03<br>±0.18 | 1.4<br>±0.86  | 0.83<br>±0.38 | 0.07<br>±0.25 | 1.17<br>±0.95 | 0.57<br>±0.5  | 0.23<br>±0.43 | 0.03<br>±0.18 | 1.1<br>±0.96  | 0.5<br>±0.51  | 0.07<br>±0.25 | 1.23<br>±0.68 | 0.43<br>±0.5  | 0.3<br>±0.47  | 0.03<br>±0.18 | 1.33<br>±0.66 | 0.53<br>±0.51 |  |
| Difference                            | 0.03          | 0.13          | 0.13          | 0             | 0             | 0.17          | 0.07          | 0.03          | 0.13          | 0.07          | 0.07          | 0             | 0.3           | 0.17          | 0.03          | 0.1           | 0.2*          | 0             | 0             | 0.17          | 0.23*         |  |
| <b>Expert C</b>                       |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |  |
| Test                                  | 0.03<br>±0.18 | 1.47<br>±0.9  | 0.93<br>±0.25 | 0.27<br>±0.58 | 0.03<br>±0.18 | 1.57<br>±0.82 | 0.93<br>±0.25 | 0.03<br>±1.18 | 1.3<br>±0.88  | 0.6<br>±0.5   | 0.33<br>±0.55 | 0.03<br>±0.18 | 1.4<br>±0.86  | 0.67<br>±0.48 | 0.03<br>±0.18 | 1.37<br>±0.56 | 0.67<br>±0.48 | 0.37<br>±0.61 | 0.03<br>±0.18 | 1.5<br>±0.57  | 0.73<br>±0.45 |  |
| Retest                                | 0.07<br>±0.25 | 1.33<br>±0.92 | 0.8<br>±0.41  | 0.2<br>±0.41  | 0.03<br>±0.18 | 1.4<br>±0.86  | 0.83<br>±0.38 | 0.07<br>±0.25 | 1.17<br>±0.95 | 0.6<br>±0.5   | 0.27<br>±0.45 | 0.03<br>±0.18 | 1.1<br>±0.96  | 0.5<br>±0.51  | 0.07<br>±0.25 | 1.27<br>±0.64 | 0.43<br>±0.5  | 0.3<br>±0.47  | 0.03<br>±0.18 | 1.33<br>±0.66 | 0.53<br>±0.51 |  |
| Difference                            | 0.03          | 0.13          | 0.13          | 0.07          | 0             | 0.17          | 0.1           | 0.03          | 0.13          | 0             | 0.07          | 0             | 0.3           | 0.17          | 0.03          | 0.1           | 0.23*         | 0.07          | 0             | 0.17          | 0.2*          |  |

\*p<0.05

errors during the retest stage, particularly in tasks involving head-on collisions. This indicates the effectiveness of the sponge motor modification as a methodological improvement in reducing injury risk during simulated falls.

Both the STBIDF-M [5] and its original version, the three-task STBIDF [11], are unique tools for measuring a phenomenon that has only recently begun to be explored [8]. In the classic study of reliability using the 'test-retest' method for non-motor psychological and pedagogical tests, it is generally expected that the original results will be confirmed after several days of repeated testing under identical experimental conditions. Whether or not these expectations are met is documented by the correlation coefficient ( $r$ ) value. However, these tests, which measure the SFI phenomenon, incorporate motor modifications of increasing difficulty.

At the methodological core of these modifications are three partly enthymematic assumptions. First, pressing the sponge with the chin to the chest and clapping the hands should reduce errors during hand-head collisions. In Task 2 of the STBIDF, the instructions state: "From the vertical posture, press the sponge with the chin to the chest, on the command READY start clapping hands, and on the command GO lie on your back again" [11]. Secondly, increasing the coordination difficulty of each successive task can be counterproductive for some individuals. For example, in Task 3 of the STBIDF (the final task), participants perform the same actions as in Task 2 but with the added challenge of a backward jump from a 20 cm elevation. Thirdly, some individuals exhibit stable motor responses during ground collisions resulting from falls. The continuum of responses ranges from an absence of errors during these motor simulations to the maximum accumulation of both quantitative and qualitative errors.

Therefore, it makes sense to categorize participants into three groups: 'stable' (those who either consistently make errors or correctly protect distal body parts despite the increasing difficulty of the conditions under which a fall is inevitable); 'reducers' (those who show a reduction in errors related to distal body parts colliding with the ground during a fall under laboratory conditions, either completely or to a limited extent); and 'augmenters' (those who demonstrate an increase in such errors during a simulated backward fall). The results of studies to date have shown that individuals classified as 'stable' in the extremely positive sense ( $\text{Index}_{\text{SBIDF-M}} = 0$  points each time) are rare [13]. This pertains only to diagnostic testing, not to the intervention programme stage. A different case is that of a student who was diagnosed with an  $\text{Index}_{\text{SBIDF}}$  of 14 points before the one-year experiment and, after the experiment, showed

a reduction of all errors [28]. This is an isolated example of an extremely positive case among the 'reducers'.

We were inspired to make this division by the results of the study by Gąsienica Walczak and A. Kalina [13]. The authors found that among 213 physiotherapy and physical education students, 160 (75.12%) had suffered injuries as a result of a fall. In this group, 14 students (8.75%) with a history of traumatic falls made a series of errors involving four observed body parts during the three STBIDF tasks. Since the test consists of three tasks and four body parts are observed, the number 12 is typically associated with the quantitative evidence of a set of errors for those unfamiliar with the details. However, the evaluation of errors involving the legs, although observed in each of the three tasks, is only documented by the results of Task 3 in the STBIDF [8,11]. Therefore, the number 10 may or may not serve as empirical evidence of a complete set of errors. "Maybe" because errors involving the hands, observed in each of the three tasks, can be documented with two points (6 in total), and errors with the legs, one at a time, result in 2 points, leaving only 2 points missing for a total of 10. Since errors involving the hips and head are evaluated three times using the "zero-one" scoring system, this combination of scores indicates that the person did not make an error on four occasions.

Only a score of 14 points ( $\text{Index}_{\text{SBIDF}}$ ) serves as evidence of complete errors in both a quantitative and qualitative sense. The quantitative assessment of this score indicates "complete repeatability of errors", while the qualitative assessment suggests "resistance to motor modification and impaired cognitive functions". This qualitative assessment was also assigned by the researchers to six students who scored 13 points on the  $\text{Index}_{\text{SBIDF}}$ . However, these students differ from the others in their quantitative assessment, which revealed a "higher weight of first-degree errors (61.54%)". Two students with an  $\text{Index}_{\text{SBIDF}}$  score of 12 points quantitatively demonstrated a "moderate dominance of first-degree errors (80%)", while qualitatively showing "very low cognitive-behavioral potential". For three students with an  $\text{Index}_{\text{SBIDF}}$  score of 11 points, the quantitative assessment indicated a "dominance of first-degree errors (90%)", and the qualitative assessment reflected their "cognitive-behavioral limitations" [13].

The results of the study by Gąsienica Walczak and A. Kalina [13] were not derived from a 'test-retest' procedure, so it is impossible to hypothesize about the repetition of these characteristics (profiles) within a short time interval. On the other hand, the published results of the STBIDF 'test-retest' procedure, based on the observations of 35 students, do not provide information about the proportions of individuals according to the

proposed breakdown [12]. However, it is known that in that validation procedure, two experts observed a maximum Index<sub>SBIDF</sub> score of 14 points during the 'test' stage. There is no data available to determine whether this was an isolated result or if it applied to other individuals as well. During the 'retest' stage, two experts again reported a maximum score of 14 points, but the final consensus was 12 points. This adjustment still does not clarify whether the maximum score (or any score of 14 points) from the 'test' stage is related to the 12-point score from the 'retest' stage.

Here, we highlight the omission of the number of observations related to extreme outcomes in the available estimations. Litwiniuk [29] and Litwiniuk et al. [30,31] provided examples illustrating the importance of this information when selecting individuals for various intervention groups (such as rescue teams, police, military, etc.). These groups often consist of individuals with different ages, genders, and specific competencies across various fields, but with a desired similarity in motor potential.

Valuable, though general, knowledge about the effect of motor modifications in successive STBIDF tasks on the cognitive-behavioral domain of the subjects was provided by the correlation coefficients of tasks repeated 7 days apart. These correlation values are higher than those found in our study: task one  $r = 0.816$ , task two  $r = 0.772$ , task three  $r = 0.572$ , and  $\text{Index}_{\text{SBIDF}} r = 0.865$  [12].

The decreasing  $r$ -values are a consequence of the motor modifications and, combined with the lower arithmetic means of the sum of errors for each task and the overall STBIDF score during the 'retest', suggest a trend toward error reduction. It is not surprising that the error-reduction process proved to be relatively slow, as 'self-education' using the STBIDF involves only two motor modifications during three simulated backflips under laboratory conditions – each time the test is applied [12]. Our validation results provide evidence that augmenting the motor modifications with three additional tasks, compared to the original STBIDF structure, has a statistically significant error-reducing effect starting from Task 5 in the STBIDF-M. Statistically significant differences in the mean scores of Task 5 and Task 6 were unanimously confirmed by all experts.

The authors of the STBIDF 'test-retest' procedure [12] did not report the proportions of students classified as 'stable', 'reducing', or 'increasing'. Our analysis of repeated 'test-retest' STBIDF-M scores revealed two students (S1a and S1b) with identical profiles in terms of total scores and their structure ( $\text{Index}_{\text{SBIDF-M}} = 18$  points), and one student (S2) with an  $\text{Index}_{\text{SBIDF-M}}$  score of 8 points ( $r = 1$ ). In the group

of students 'augmenting errors', we found two identical  $\text{Index}_{\text{SBIDF-M}}$  profiles: a male student (M2b, 21 years old) and a female student (M2c, 20 years old), with scores of 9 points in the 'test' stage and 15 points in the 'retest' stage. While the low positive correlation ( $r = 0.265$ ) between their profiles in the 'test' stage was not statistically significant, the correlation in the 'retest' stage was significant ( $r = 0.640, p < 0.05$ ).

The examples of different outcome calculations cited here demonstrate the multifaceted nature of these phenomena, while also highlighting their significant cognitive potential.

The aim of the 'test-retest' procedure, in the standard sense, is not to establish the proportions of individuals by the error criterion (or lack thereof) mentioned above, nor to correlate the profiles of individuals with identical initial characteristics. However, the results of our validation procedure provide evidence that a meaningful synthesis can be achieved through a complementary approach [7,32]. Thus, the STBIDF-M meets methodological expectations by identifying individuals according to their sensitivity to motor modifications related to personal safety [33,34]. In this regard, it is an innovative tool in the fields of health prevention and survival in the broadest sense. On one hand, SFI profiles based on this methodology can be applied to the design of intervention programmes that follow the pedagogical principle of individualisation. On the other hand, it allows for the prediction of potential injuries resulting from unintentional falls.

## Conclusions

The results of this 'test-retest' procedure highlight the unique and non-standardised opportunities for analyzing and synthesizing outcomes using this fundamental method. This was made possible by the innovative motor structure of the STBIDF-M, which extends beyond methodological advancements. Observations of the unconscious behaviors and actions of participants provide valuable insights into cognitive and intellectual phenomena related to human personality. We recommend that the authors of STBIDF and STBIDF-M (as they possess the raw data) conduct a secondary analysis and synthesis of the collected empirical data to further enrich this understanding.

## Funding

The authors declare that no specific grant from any funding agency in the public, commercial, or not-for-profit sectors was used for this research.

## Conflicts of Interest

The authors declare no conflicts of interest.

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Cite this article as:

Kruszewski A, Litwiniuk A, Waszkiewicz E. Reliability and objectivity of the new version of the ‘susceptibility test for body injuries during a fall’ (STBIDF-M) in physiotherapy students. *Physical Education of Students*, 2024;28(5):303–312.

<https://doi.org/10.15561/20755279.2024.0507>

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Received: 15.09.2024

Accepted: 23.10.2024; Published: 30.10.2024

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### **Information:**

#### **Sponsors, Partners, Sponsorship:**

Ukrainian Academy of Sciences.

SCIENTIFIC EDITION (journal)

Physical Education of Students, 2024;28(5)

Editorial to the publisher department:

certificate DK No 7472; 07.10.2021

-----  
designer - Sergii Iermakov

editing - Tetiana Yermakova T.

administrator of sites - Sergii Iermakov

designer cover - A. Bogoslavets  
-----