# The relationship of postural asymmetry to inspiratory and expiratory pressure of young women

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**Research Article**

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## Abstract

# Introduction

Breathing mechanic is determined by tonus and flexibility, correct contraction amplitude of the thoracic diaphragm, relaxation, and the activity of auxiliary muscles. Respiratory muscle strength is evaluated by measuring the static maximal inspiratory (MIP) and expiratory (MEP) pressures. The aim of this research was to determine the relationship between MIP and MEP and body posture in female soccer players.

# Material and methods

The research involved a group of 57 women aged 16–20 years (42 soccer players and 15 controls) without disorders in the movement apparatus, cardiovascular system, or respiratory system. MIP and MEP were measured and analyzed with respect to body posture in three different positions. MIP and MEP values were evaluated with Micro Respiratory Muscle Analyzer (CareFusion). The body posture in the coronal plane from the back measured with a non-contact 3D photogrammetry system.

# Results

Asymmetries in body posture were also measured and compared between groups. Asymmetry was observed at all anatomical locations in each of the postural positions, with an increase in asymmetry of the scapulae in the soccer players ($p = 0.008$). The control group had increased asymmetry at the skull nuchal line.

# Conclusions

These results draw attention to the need for standardizing the evaluation procedure for respiratory muscle strength and interpretation of results. Postural measurements allow linkage of specific postural errors to the maximum strength of inspiratory and expiratory muscles. The asymmetrical location of the scapulae may be followed by a disturbance in the maximum strength of the inspiratory muscles.

## Key Points Summary

- Changes in maximum inspiratory muscle strength may change as a result of postural asymmetries.
- Female soccer players have greater static respiratory muscle strength than non-athletes.
- These results help us understand the relationship between postural anomalies and respiratory function.

## Introduction

The breathing sequence consists of two phases in which the superficial and deep muscles of the neck, chest, and abdomen are engaged by controlling two integrated mechanical pumps – pressing (heart) and suction (chest) - to fill the lungs with atmospheric air. During inhalation, the contraction of the primary respiratory muscles (diaphragm and external intercostals) increases the negative pressure in the chest by lowering the diaphragm cupola. With difficult and intensified inhalation, these muscles are supported by the accessory respiratory muscles [1, 2].

The role of the diaphragm is not limited to breathing, and it participates in the activity of the abdominal organs, and affects the cervical and thoracic segments of the spine and the underbelly due to functional and structural interrelations [3].

The global assessment of respiratory muscles static fitness was invented by Black and Hyatt, who determined reference values for healthy people of different sexes and ages [4]. Other studies observed differences in the range of MIP and MEP values according to age, sex, and race of the analyzed population [5–9]. Observations revealed that, for healthy and physically fit people, MEP parameters are generally higher than MIP, and lower maximum pressure ranges are sufficient for normal respiratory function [10]. In pathological conditions with increased respiratory resistance, those ranges may be insufficient for proper lung ventilation. MIP and MEP values are lower in patients with severe chronic obstructive pulmonary disease (COPD) compared to healthy subjects, and the maximum inspiratory pressure decreases in people with mild and moderate functional disorders [11]. According to the reports, MIP is a good indicator for assessing the degree of respiratory muscle disorders in various diseases [12–15]. Ghanbari et al. analyzed improvement of MIP value as a result of the breathing muscle training. They found that the type and duration of exercise had an impact on athletic performance, strength, and endurance of respiratory muscles [16]. There are few reports regarding the assessment of muscle strength in athletes [17–20], as well as the effects on respiratory muscles in healthy individuals with postural errors [21, 22].

The goal of the study was to assess the relationship between the maximum inspiratory pressure (MIP) and expiratory pressure (MEP) and body posture in female soccer players. This research is a continuation of the studies regarding the physical health of young female soccer players [23].

# Methods

The research was carried out in February 2017 in Biała Podlaska, Poland. The bioethics committee at the Warsaw Medical University approved the study under No. KB/49/2017. Each participant was notified about the purpose, voluntary nature, and non-invasiveness of the measurements, and was asked to give their written informed consent for participation (signed personally or by parents/legal guardians in the case of participants under 18). Additionally, a questionnaire consisting of several questions necessary for analysis was completed. All methods were carried out in accordance with relevant guidelines and regulations.

## Participants

A group of 57 women aged 16–20 years was examined. Forty-two were playing soccer in the club AZS PSW Biała Podlaska. Club is classified in the Ekstraliga Kobiet – Polish female Premier League with 278 players in the 2016/2017 season. The remaining 15 volunteers were a control group without any pathological anomalies in the motor, respiratory, and circulatory systems. The group of soccer players was dominated by girls with primary education (78%) living in cities (10–100 thousand inhabitants), and the control group 60% had received secondary education and 53% lived in the countryside. Half of the soccer players had 6 or more years or playing experience, 45% had 3–5 years, and 5% had less than 2 years of experience. Training lasted less than 2 hours for 98% of players, with a frequency of 5–7 times a week (54.8%) to 1–2 times a week (7.2%). Participants engaged in occasional swimming, individual strength training, and cycling. In the control group, the subjects rarely swam or participated in a strength training or organized exercises, but had a higher frequency of cycling activity.

## Measurements

MIP and MEP were measured with a non-invasive, handheld Micro Respiratory Muscle Analyzer (CareFusion). The device is widely used for reliability tests in both the sitting and standing positions, and meets the standards of the American Thoracic and European Respiratory Societies [10]. Participants were instructed on how to insert the mouthpiece, and how to perform the necessary maneuvers. During the measurements, the participants were verbally encouraged to exert maximum effort. MIP was measured three times at an innermost inhalation (TCL – total lung capacity), and at 1–2 minute intervals. MEP was measured after a deep exhalation (RV – residual volume), and three times at the same intervals as MIP.

The body posture of the subjects was assessed from the dorsal coronal plane using a non-contact 3D photogrammetry system according to previously published methods [23, 24]. Each participant stood inside the calibrated area with their back turned to the cameras, in a relaxed position with legs upright and slightly spaced feet, arms along the torso, and with their eyes facing forward. All participants wore underwear and a silicone head cap. Circular markers with a diameter ø10 mm were applied to the selected bone landmarks. To analyze postural asymmetry of the subjects, the following anatomical landmarks were selected: $O_{CL}$, $O_{CR}$ – the bilateral outermost points of the inferior nuchal line of the skull; $S_{CUL}$, $S_{CUR}$ – the position of the trigonum spina scapulae, bilaterally; $S_{CLL}$, $S_{CLR}$ – the position of the inferior scapular angles, bilaterally; and $P_{VL}$, $P_{VR}$ – the bilateral rear upper iliac spines. A group of vectors was determined for analysis (Fig. 1):

$$\overline{Oc} = O_{CL} - O_{CR} \quad (1)$$

$$\overline{S_{CU}} = S_{CUL} - S_{CUR} \quad (2)$$

$$\overline{S_{CL}} = S_{CLL} - S_{CLR} \quad (3)$$

$$\overline{P_V} = P_{VL} - P_{VR} \quad (4)$$

Three body positions were analyzed: Resting (habitual, Hab 1), Upright (actively corrected, ActCor), and resting post-MIP/MEP measurement (Hab 2).

# Statistical Analysis

For statistical analysis, the R package version 3.6.2 was used. Normality of data distribution was verified by “shapiro.test” function, which performs the Shapiro-Wilk test. The dNon-normally distributed data were analyzed using “wilcox.test”, the two-sided non-parametric Mann-Whitney-Wilcoxon on the significance level on 0.05Mann-Whitney U or Wilcoxon tests. MIP and MEP values are reported as means. All the functions were a part of the “stats” package in version 3.6.2. A p-value less than 0.05 was determined to be statistically significant.

# Results

Body mass and BMI were not associated with higher MIP and MEP measurements (Table 1). A statistically significant difference was observed in the maximum static expiratory pressure values ($p = 0.002$) (Figs. 2 and 3**)**. Results of MIP and MEP values were compared with other researchers in Table 2.

Table 1
Anthropometric characteristics and mean of MIP and MEP of the examined groups, two-sided non-parametric Mann-Whitney-Wilcoxon test, $p < 0.05$.

| | **Soccer players (n = 42)** | **Control group (n = 15)** | **p-value** |
|---|---|---|---|
| Body mass (kg) | 58,3 ± 6,7 | 55,5 ± 7,5 | 0,012 |
| BMI ($kg/m^2$) | 21,0 ± 2,3 | 20,2 ± 2,6 | 0,006 |
| MIP (cm $H_2O$) | -81,53 ± 21.88 | -72,86 ± 19,69 | 0,099 |
| MEP (cm $H_2O$) | 103,81 ± 25,33 | 88,86 ± 22,93 | 0,002 |

Table 2
Results of MIP and MEP measurements obtained in the test in relation to literature.

| | **Soccer players (n = 42)** | **Control group (n = 15)** | **Leech et al. 13–35 age** | **Ringqvist 18–29 age** | **Cook et al. 18–32 age** |
|---|---|---|---|---|---|
| MIP (cm $H_2O$) | -81,53 ± 21.88 | -72,86 ± 19,69 | -85 ± 28 | -113 ± 24 | -100 ± 19 |
| MEP (cm $H_2O$) | 103,81 ± 25,33 | 88,86 ± 22,93 | 95 ± 29 | 170 ± 29 | 146 ± 34 |

Positive values in postural measurements indicate a lowering of one of the bone points on the right in relation to a corresponding point on the left side of the body. Asymmetry was evident in all three measured postural positions (Table 3**).**

Table 3

Results of measurements of the posture changes (vectors as in Eq. 1–4) in each of the adopted posture type (in reference to description given in section Measurements). Socc – soccer players (n = 42), Ctrl – controls (n = 15), two-sided non-parametric Mann-Whitney-Wilcoxon test, $p < 0.05$.

| | | Hab 1 | | ActCor | | Hab 2 | |
|---|---|---|---|---|---|---|---|
| | | Socc | Ctrl | Socc | Ctrl | Socc | Ctrl |
| Inclination angle of superior nuchal points of the skull to the horizontal [°] | max: | 5,83 | 6,77 | 5,19 | 7,97 | 7,23 | 6,99 |
| | min: | -3,06 | -4,59 | -2,24 | -3,05 | -3,38 | -5,47 |
| | max-min: | 8,89 | 11,36 | 7,43 | 11,02 | 10,61 | 12,46 |
| | mean (SD): | 1,29 ± 2,07 | 2,32 ± 2,64 | 1,37 ± 1,94 | 1,81 ± 2,77 | 1,48 ± 2,11 | 1,58 ± 2,66 |
| | median: | 1,18 | 2,28 | 1,34 | 1,94 | 1,27 | 1,82 |
| | p-value: | 0,055 | | 0,562 | | 0,574 | |
| Inclination angle of trigonum spina scapulae to the horizontal [°] | max: | 8,36 | 5,9 | 8,88 | 6,54 | 6,41 | 5,5 |
| | min: | -5,73 | -3,44 | -7,01 | -3,36 | -4,94 | -3,76 |
| | max-min: | 14,09 | 9,33 | 15,89 | 9,89 | 11,35 | 9,26 |
| | mean (SD): | -0,13 ± 2,61 | -0,15 ± 2,12 | 0,34 ± 2,88 | 0,07 ± 2,55 | -0,12 ± 2,31 | -0,02 ± 2,21 |
| | median: | -0,06 | -0,39 | 0,2 | -0,33 | -0,1 | 0,21 |
| | p-value: | 0,660 | | 0,574 | | 0,874 | |
| Inclination angle of inferior angulus scapula to the horizontal [°] | max: | 5,96 | 2,81 | 5,68 | 1,83 | 5,08 | 2,21 |
| | min: | -5,39 | -3,88 | -5,35 | -3,53 | -5,8 | -4,38 |
| | max-min: | 11,35 | 6,69 | 11,02 | 5,36 | 10,88 | 6,59 |
| | mean (SD): | -0,5 ± 2,86 | -1,16 ± 2,00 | -0,21 ± 2,99 | -1,24 ± 1,57 | -0,58 ± 2,88 | -1,07 ± 1,95 |
| | median: | -0,45 | -1,62 | -0,35 | -1,11 | -0,63 | -1,5 |
| | p-value: | 0,527 | | 0,237 | | 0,610 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Inclination angle of spina iliacus posterior inferior to the horizontal [°] | max: | 2,83 | 0,81 | 2,62 | 0,76 | 2,69 | 0,85 |
| | min: | -7,26 | -4,01 | -7,37 | -3,87 | -6,67 | -4,01 |
| | max-min: | 10,09 | 4,82 | 9,99 | 4,63 | 9,36 | 4,86 |
| | mean (SD): | -3,51 ± 2,13 | -2,14 ± 1,29 | -3,51 ± 2,12 | -2,19 ± 1,33 | -3,48 ± 2,03 | -2,17 ± 1,29 |
| | median: | -3,47 | -2,02 | -3,61 | -2,24 | -3,55 | -2,24 |
| | p-value: | 0,011 | | 0,016 | | 0,012 | |

The control group had greater asymmetry at the skull nuchal line in all analyzed body postures. The relative position of $O_{CL}$ vs. $O_{CR}$ points changed after measuring MIP and MEP in all participants. However, changes in maximal respiratory pressure were not dependent on the vector location. A tendency for MIP dependence on the angle of the cervical vertebrae extreme points was observed in the soccer players in the upright position after the measurement was taken. The distribution of MIP/MEP values were: Hab 1 (MIP: r=0.22, p=0.148; MEP: r=0.08, p=0.601);

ActCor (MIP: r = 0.44, p = 0.003; MEP: r = 0.16, p = 0.293);

Hab 2 (MIP: r = 0.38, p = 0.012; MEP: r = 0.06, p = 0.707).

A relationship between the asymmetric arrangement of the scapulae (vectors and ) and changes in MIP and MEP values was not observed. Although there were players with lower $O_{CL}$ values than the controls, the increase in $S_{CUL}$ and $S_{CLL}$ was more significant.

Despite the threefold decrease in $P_{VR}$ vs. $P_{VL}$ in the soccer players compared to controls, this difference was not associated with statistically significant changes in MIP and MEP.

The mean MIP value was − 73.82 ± 21.71 for soccer players and − 61.81 ± 25.0 in the control group, and MEP values were 94.82 ± 24.68 and 76.76 ± 23.64, respectively. The difference between mean MIP and MEP values between the two groups was 16% and 19%, respectively. Soccer players presented a higher static strength of the respiratory muscles (r = 0.48, p = 0.001) compared to the control group (r = 0.63, p = 0.013).

A statistically significant difference (p = 0.008) was observed in MIP values related to the spatial position of the scapular triangles in the group of soccer players. In positions Hab 1 and Hab 2, the MIP was inversely proportional to the asymmetry of the scapulae (r = − 0.40), and the correlation decreased to r = -0.31 in the ActCor measurement. No correlation was established between MEP and scapular location. Respiratory muscle static strength did not change in relation to postural asymmetries.

# Discussion

There are many reports analyzing athletes of various disciplines in the context of physical performance and/or injuries. During training, the body undergoes transformations not only within the myofascial system, but also specific adaptation in many organs and systems. While internal organs undergo changes at a slower rate and are able to adapt more easily, disruptions in function of the motor apparatus may manifest faster and with greater effects [1]. Errors in a body posture associated with an abnormal inspiratory or expiratory chest position can be a basis for progressive postural dysfunction, with a loss of functional diaphragm tension and muscle stabilization of the torso [2, 3]. Pinheiro et al. showed a decrease in respiratory muscle strength and related changes in the thoracic-abdominal breathing track after experiencing stroke [25]. Disorientation of body posture that starts from the neck may be dependent on the breathing mechanism. Breathing through the mouth, which is associated with a lower MIP value, promotes frontal inclination of the head, limiting the diaphragm and chest expansion [26].

There were no significant differences in the MIP and MEP parameters correlated with body weight and BMI in our study population. Despite varied physical activities, all participants were characterized by similar anthropometric features. Other studies observed that differences in the maximum values of respiratory muscle pressure were generally related to BMI classification, as well as the environment [8, 9]. The published reference values MIP and MEP show high variability depending on the population, measurement method, and applied test methodology, as reported by Leech et al. [27], Ringqvist [9] and Cook et al. [28] (Table 2). The values we obtained are most similar to those given by Leech et al., specifically for 13–35 year-old women. The observation that maximum muscle pressure was greater in soccer players indicates that expiratory muscle strength (mainly the abdominal muscles) may be a result of increased activity, causing stimulation of breathing with physical exertion. These changes also support inspiration due to the increased initial length of diaphragm fibers. Watsford et al. also observed a higher MEP value for athletes, and stated that it can contribute to improving the efficiency of the system [29].

According to our knowledge, this is the first study that analyzes MIP and MEP results with the body posture of women practicing soccer, an endurance sport with high energy consumption. The body posture of the soccer players indicated a rate of asymmetry of the vector that was twice as high as controls. Conversely, the control group demonstrated greater asymmetry of the vector. These differences support the idea that continuous changes occur in the location of selected bone points as a consequence of unstable posture, but also illustrate disturbances in static muscle balance. It is assumed that functional postural dysfunctions, like the effects of frequently repeated aversive movement patterns, modulate neuromuscular stimulation in the torso muscles, with simultaneous regulation of the pressure in the abdominal cavity and chest [3]. An example of a dysfunction that modulates the efficiency of the respiratory system is the upper-junction syndrome, which is accompanied by a pattern of breathing using only the upper fibs, followed by potentially harmful cervical spine disorders, reduced diaphragmatic efficiency, and adaptive tonus changes in the muscles. The correlation between bending strength, straightening of the cervical spine, and the strength of the respiratory muscles was described by

Dimitriadis et al. for a group of 45 people with chronic neck problems. The MIP (r=0.35) and MEP (r=0.39) values decreased by 13.8% and 15.4%, respectively, in these patients compared healthy controls [21]. Wirth et al. analyzed neck pain in the context of MIP and MEP changes, and implicated the need to perceive musculoskeletal deficits in the spine and chest in the regression of respiratory muscles [30].

We did not observe any significant influence of $O_{CL}$ and $O_{CR}$ points asymmetry on the maximal inspiratory and expiratory muscle strength with any of the analyzed body positions in the control group. There was only a tendency for correlation between the MIP and the angle between the horizon and vector in the actively corrected position, the mechanism activating the postural muscles. The rotational positioning of the head in space is often accompanied dislocation of the scapulae. The increased asymmetry of the left trigonum spina scapulae and left inferior scapular angle in the soccer players may be related to clinical upper-cross-over syndrome, i.e. tension and shortening of the upper part of the trapezius, levator scapulae, and sternocleidomastoid. Left scapulae dislocation in the soccer players may result from repeated left upper limb movements used to coordinate the right leg while leading and/or kicking the ball. The MIP and MEP mean values were used to analyze the myofascial upper-torso with the strength of the respiratory muscles, with an inversely proportional dependence of scapular position on maximum inspiratory pressure in the soccer players. No similar reports were found in the literature, indicating a need for further assessment.

Among the studied groups, the correlation between respiratory muscle strength and increased pelvic asymmetry was not observed. However, it can be assumed that inspiratory and expiratory muscles training would have had an indirect beneficial effect on the perception of body posture [3, 21, 22, 31].The present study was a pilot study, and only considered the assessment of body posture in the dorsal coronal plane, which possessed minimal initial correlation with the role of respiratory muscles. A noticeable limitation of the presented research is the variability of MIP and MEP values, related to the number of repetitions performed for each maneuver and how they are interpreted. Further tests require an increased number of repetitions. Unfortunately, this would significantly increase the time designated for each procedure, which affects both the researchers and participants.

# Conclusions

- • Assessment of the posture in the dorsal coronal plane permits assessment of specific errors in body posture accompanied by the maximum strength of inspiratory and expiratory muscles.
- • Asymmetrical location of the scapulae may be followed by disturbances in the maximum strength of the inspiratory muscles.

The research can be summarized in few additional translational perspectives. Physiotherapists and doctors can consider the correlation between the asymmetrical position of the head and shoulders in the context of the inspiratory muscle deficits. Local body asymmetries may be associated with interval training, including intensive work of the arms that may cause discomfort and tension in the neck. Trainers should consider including exercises for the inspiratory muscles to potentially improve exercise tolerance and sprint performance.

# Declarations

**DATA AVAILABILITY**

Data generated or analysed during this study are included in this published article.

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**Conflict of interest disclosure:** The authors declare no conflicts of interest.

**Author Contributions:**

SP: data processing, calculations, numerical and statistical analysis, preparation of the tables, writing of the manuscript

MS: development, construction, calibration of the measuring system, measurements, data preparation, analysis and processing, preparation of the figures, writing, processing and editing of the manuscript

TG: logistic and organizational work

BŻ: medical guidelines for research, measurements, interpretation of the results, discussion, conclusions, writing of the manuscript

All authors approved the final draft of this manuscript and agree to be accountable for all aspects of the work to ensure that questions related to the accuracy or integrity of any part are appropriately investigated and resolved.

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# Figures

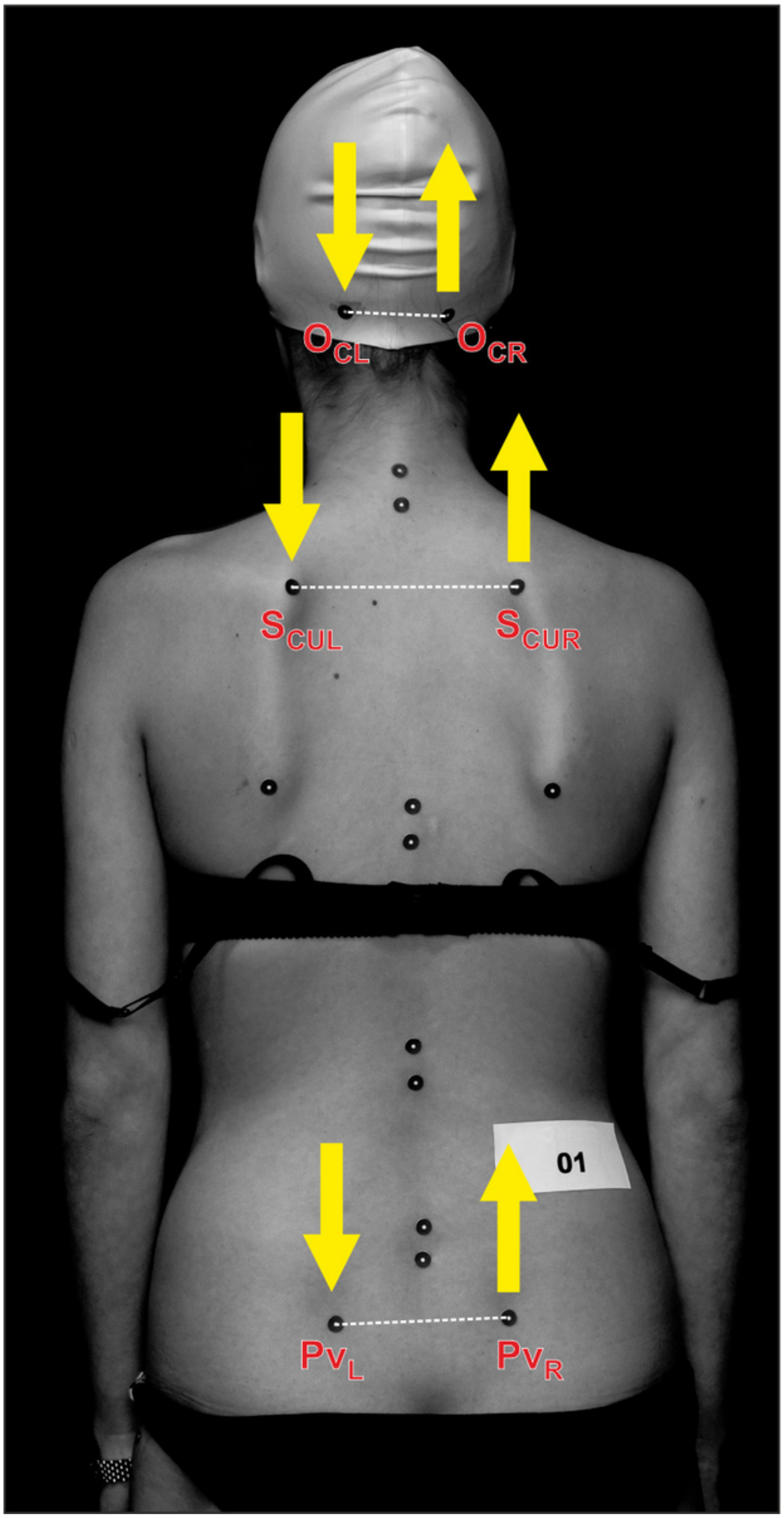


Figure 1

Spatial coordinates (x, y, z) of the selected body points in the optical measurement system. An example of the analyzed body points ($O_C$, $S_{CU}$, Pv – bilaterally) and their mutual relationships are shown.

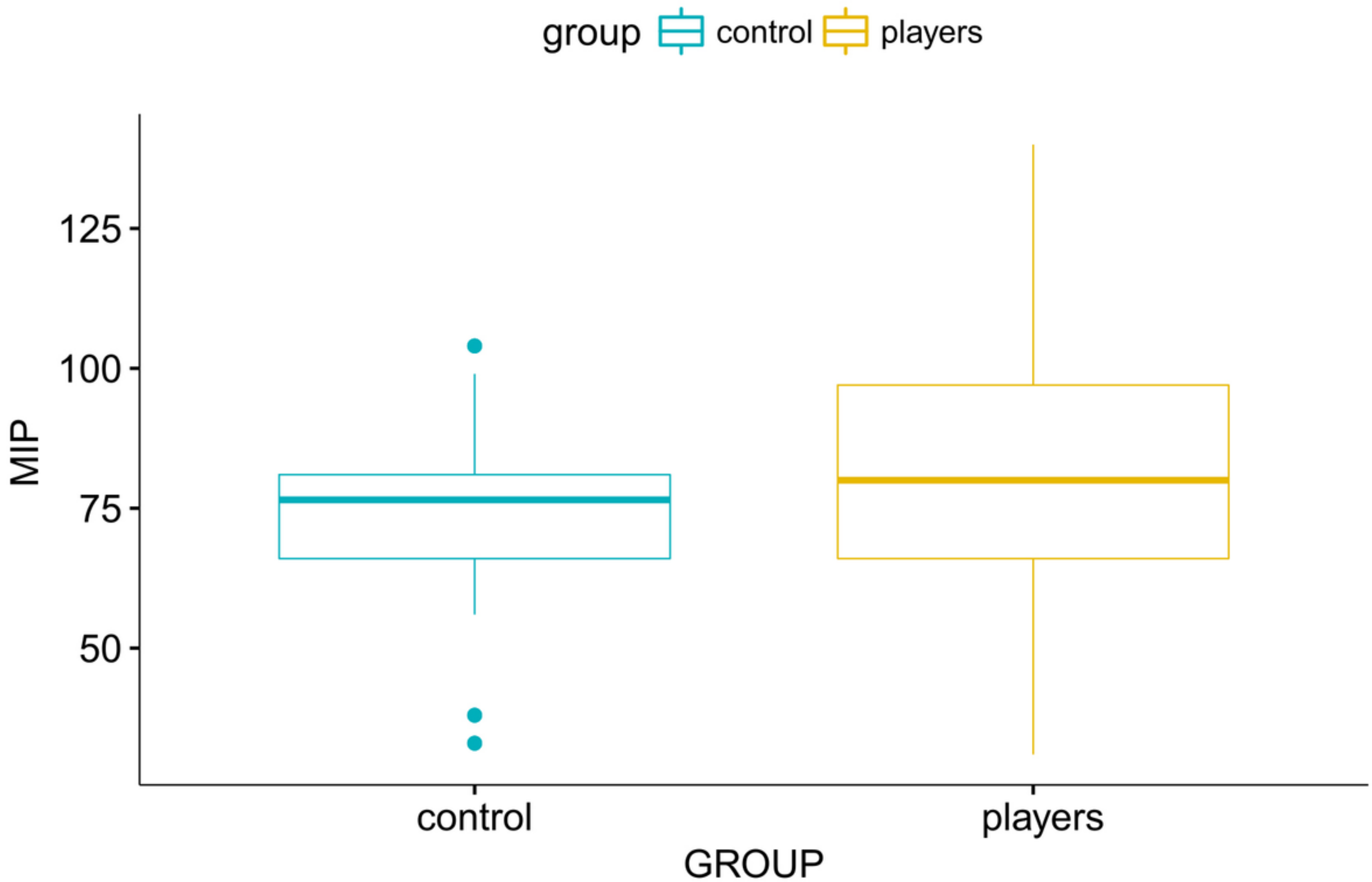


Figure 2

Relationship of MIP between controls and players (p=0.099)

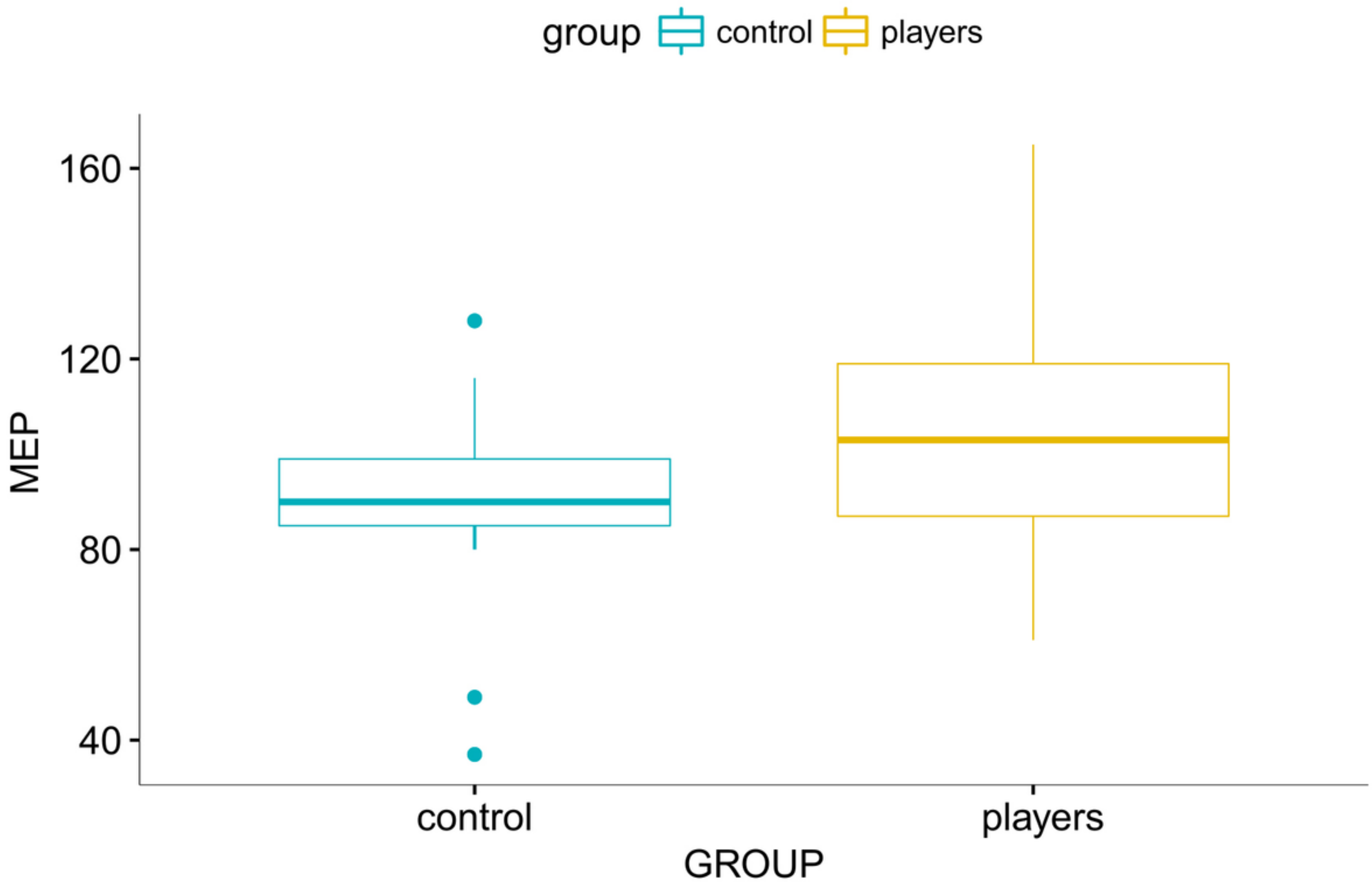


**Figure 3**

**Relationship of MEP between controls and players (p=0.002)**

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- resultscontrolgrouprawdata.xlsx
- resultsfplayergrouprawdata.xlsx