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ORIGINAL ARTICLE

Effects of asymmetric trunk muscle fatigue on pelvic inclination and rotation

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ABSTRACT

Although the influence of muscle activity on the pelvic position has been proven, research on the influence of (asymmetric) muscle fatigue on the pelvic position is inconsistent. The purpose of the present study was to assess the effects of asymmetric fatigue of the lateral trunk muscles on the pelvic position based on a pre/post/follow-up design. For the final data analysis, 38 subjects (20 men, 18 women; age 22.63 ± 3.91 years) were asked to perform side bends in sets of 20 repetitions on a Roman chair until complete exhaustion. For pre-, post-, and follow-up test (24 h after treatment), pelvic positions were recorded with a 3D photogrammetric scan. Statistical analysis showed no systematic changes in pelvic inclination and rotation after unilateral exhaustion for the three measuring times. However, highly individual, non-systematic changes in pelvic positions were present, especially between pre- and post-test. The follow-up measurements tend to return to the initial pre-test state. Unilateral fatigue of the lateral flexors of the trunk affects the pelvic position in a non-systematic way.

Keywords: Performance analysis of sport, Physical conditioning, Pelvis, Muscle soreness, Posture, Sport.

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INTRODUCTION

The position of the pelvis in space has a decisive influence on the posture of the trunk. Furthermore, it is the mechanical basis for the spine (Day et al., 1984; Jackson et al., 2000; Le Huec et al., 2011; Stylianides et al., 2013). It is determined by:

- biomechanical (e.g., leg length differences (Betsch et al., 2011; Rhodes & Bishop, 2010)),
- articular (joint status of the sacroiliac joints (Hansen & Helm, 2003; Pel et al., 2008) and the pubic symphysis (Leadbetter et al., 2004)),
- and neuromuscular factors (including the status of the trunk, thigh and pelvic floor muscles (Buchtelová et al., 2013; López-Miñarro et al., 2012; Pool-Goudzwaard et al., 2004)).

A significant number of pathological entities may result from changes in the pelvic position (Jackson et al., 2000; Jentzsch et al., 2013; Roussouly & Pinheiro-Franco, 2011; Volinski et al., 2018). Therefore, investigating possible correlations or influencing factors is of interest for functional understanding and possible therapeutic approaches (Yoo, 2013). Possible differences in static and dynamic pelvic parameters between subjects without symptoms and patients could provide important diagnostic information (Montgomery et al., 2011; Roussouly et al., 2002; Schwab et al., 2006; Smith et al., 2008; Stylianides et al., 2013; Youdas et al., 2000).

Although the influence of muscle activity on the pelvic position has been proven, research on the influence of (asymmetric) muscle fatigue on the pelvic position is inconsistent (Buchtelová et al., 2013). For example, one-sided muscle fatigue can occur in sports with asymmetrical movement sequences and occupational activities with a one-sided trunk alignment. The lateral flexors of the trunk can subsequently cause unilateral pelvic inclination or forward pelvic rotation (ante pulsion) (Buchtelová et al., 2013).

Our research goal for this study was to analyse the pelvic position before and after 24 h of unilateral fatigue of the muscles responsible for lateral flexion of the trunk. We expected a unilateral increase in pelvic rotation or inclination due to unilateral fatigue.

MATERIAL AND METHODS

Participants

Data were collected from a total of 41 healthy subjects. Illness reported pain located in the back area and recent injuries were defined as exclusion criteria. Subjects were advised to come in a rested state and not to perform intense physical activities for 48 h prior to the study. Of the initial 41 subjects, data from 38 subjects (20 men, 18 women; age 22.63 ± 3.91 years; height 173.36 ± 9.95 cm; weight 71.89 ± 12.97 kg; body fat 20.92 ± 9.58 %) were used for the final analysis. The three subjects were excluded because their execution of the exercises was not in accordance with the instructions, or data from one of the three measurement times were missing.

Our study was approved by the ethical committee of the university and met the criteria of the Declaration of Helsinki (Smith et al., 2008). All participants signed an informed consent form, including permission to publish the results of the study. Subjects were asked not to perform intense activities 48 h prior to the study and come in a rested state.

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Procedures

The subjects performed side bends on a Roman chair in sets of 20 repetitions to unilateral exhaustion of the lateral flexors of the trunk. The treatment targeted the contralateral side to the handedness side. Previous research showed the effectiveness of the protocol for introducing asymmetric fatigue in the context of side differences in skin surface temperatures (Dindorf et al., 2022). Tactile feedback (contact point to a bar at the endpoint of maximal lateral trunk flexion) was used to control the range of motion (ROM). Upward and downward movement was timed in a standardized way using a metronome. The termination criteria were defined as the following to ensure total exhaustion: a) exertion score of at least 8 on the OMNI Scale (Robertson, 2004); b) inaccurate execution across at least the last five repetitions of a set; c) over 3 sets of the specified number of 20 repetitions could not be achieved; d) ROM could not be completely maintained until the last repetition.

Photogrammetric noncontact 3D scan

Posture was measured using a photogrammetric noncontact 3D scanner (Paromed 4D, Neubeuern, Germany). Upper body clothing was removed for the measurements, and women wore sports bras.

In their habitual posture, the subjects stood barefoot at a distance of 2.5 m from the scanner. Markers were placed on the bony landmarks of C7 and S1, the most concise points of the neck and lumbar lordosis and chest kyphosis, both inferior angles of the scapula and both posterior superior iliac spines. Locations were marked with a water-resistant pen to ensure the same position for the next measuring day. Posture data was recorded three times on two different days: before the treatment (pre), directly after the treatment (post), and approximately 24 h afterward (follow-up).

Questionnaires

Additionally to the above mentioned rating of perceived exertion on the OMNI Scale (Robertson, 2004), the participants specified items from the dimension 'fatigue' of the Profile of Mood States (POMS) questionnaire (McNair et al., 1971) directly and 24 h after the treatment. On Days 2 and 3, delayed-onset muscle soreness (DOMS) was measured using the 7-point Likert scale according to (Priego-Quesada et al., 2020).

Statistical analysis

Repeated measures ANOVA were used to check pelvic position changes for the measurement times. Necessary requirements were checked and could be assumed. All groups were normally distributed according to Kolmogorov-Smirnov test. Greenhouse–Geisser adjustments were made to correct violations of sphericity. Bonferroni correction was performed for post hoc testing. Alpha level of .05 was set as the cut-off for significance. The results are reported as mean and standard deviation. Calculations were performed using SPSS Statistics (version 25, SPSS Inc., Chicago, USA).

RESULTS

On average, participants accomplished 7.27 ± 4.74 sets of lateral flexion until complete exhaustion and reported a score of 8.88 ± 1.01 on the OMNI scale post treatment. DOMS was scored at 3.78 ± 1.33 24 h after treatment and 5.05 ± 1.10 48 h after treatment.

A comparison of the 'fatigue' dimension of POMS using the average summative score showed the highest fatigue on the day of treatment (19.67 ± 7.41) and the lowest 24 h after the treatment (13.20 ± 6.98).

Figure 1. Start and end position of the treatment for introducing unilateral muscle fatigue. Side bends were performed on a Roman chair.

Table 1. Descriptive statistics (mean and standard deviation) of the evaluated pelvic variables in the measured conditions.

Variable	Pre-test	Post-test	Follow-up test
Pelvic inclination	-0.21 ± 2.17°	-0.07 ± 2.04°	-0.33 ± 2.63°
Pelvic rotation	-1.67 ± 2.53°	-1.85 ± 2.48°	-1.99 ± 2.67°

We found no statistically significant difference for pelvic inclination in the different conditions, $F (1.49, 55.22) = 0.307$, ($p = .672$), n = 38. Similarly, there was no statistically significant difference for pelvic rotation in the different conditions, $F (2, 74) = 0.411$, ($p = .664$), n = 38. Table 1 presents the mean and standard deviation of the regarded pelvic parameters at pre-, post-, and follow-up condition. Figure 1 shows measurements of five exemplary subjects; differences seem to alter the most from the pre- to the post-test for both pelvic inclination and rotation, albeit inconsistently. Measurements tend to return to the initial pre-test state after 24 hours.

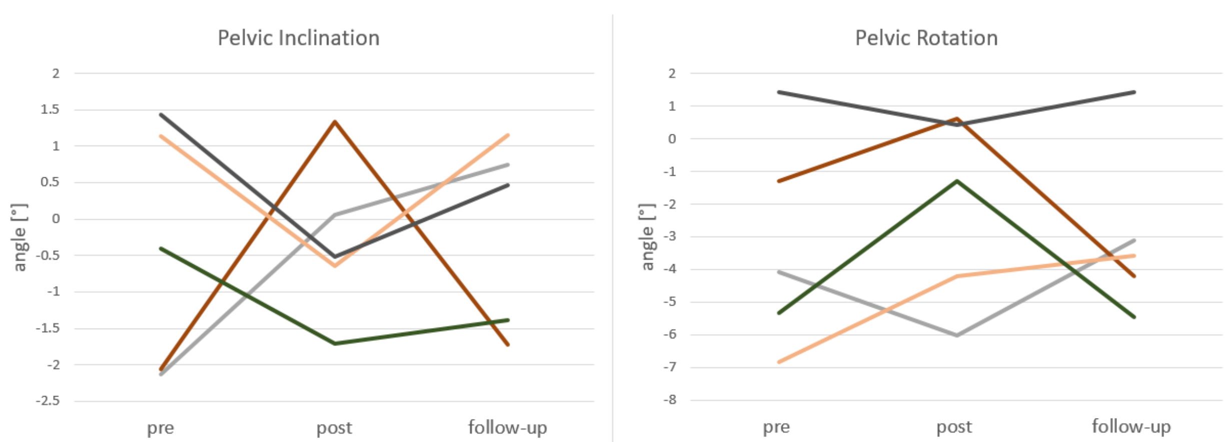

Figure 2. Exemplary measurements for five subjects. Y-Axes: negative values mean inclination or rotation to the left side.

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DISCUSSION

The results of the current study did not confirm our hypothesis that pelvic inclination or rotation changes systematically after unilateral exhaustion of the trunk flexor muscles. The results of the DOMS and OMNI tests showed a strong muscular workload with subjective fatigue (POMS) already regenerating the following day. Nevertheless, we found no statistically significant effect on pelvic inclination and rotation after unilateral exhaustion of the trunk flexors. Our study showed that changes in pelvic position were individually different in magnitude and unsystematic in direction.

On the contrary, regarding possible effects of asymmetric muscle fatigue on the pelvic position, gait, and posture (Youdas et al., 1996)showed a relationship between pelvic inclination and shortening of the back muscles but none to the hip flexors. However, it must be noted that existing studies always loaded the investigated muscle groups symmetrically and measured effects only in the sagittal plane (Yoshitake et al., 2001).

Several muscle groups are involved in the lateral flexion of the trunk. These include the rectus abdominis muscle, the obliquus internus abdominis muscle, and the quadratus lumborum muscle. The transversus abdominis muscle also contributes a rotatory component and may have been partly responsible for unilateral pelvic rotation (Schünke et al., 2022; Stokes et al., 2011; Thelen et al., 1995). Different initial muscular states (in terms of strength endurance), as well as different motor control strategies, maybe the cause of the individual differences found. It is known that in postural stabilization, different individuals show different motor activation patterns (Alvim et al., 2010).

In addition to the large trunk muscles, other muscle groups contribute to lateral flexion (e.g., M. iliocostalis lumborum, M. intertransversarii). These are partly small muscle strands that tire more quickly and may lead to the observed individually different discontinuation of the exercises but unable to influence the pelvic position.

Regarding possible limitations, although the execution of the treatment was constantly controlled and correction instructions were provided, a common mistake was, for example, the rotation of the upper body, which may have led to a shift of muscle activity to smaller, deeper muscles and explained the intraindividual differences (McGill, 2003; Thelen et al., 1995). The general measurement methodology using surface topography shows good results in terms of validity and reliability (Applebaum et al., 2021). Regarding the placement of the markers, their location was marked on the skin with a pen to ensure the same maker positioning for every measuring day. The cause of the unsystematic changes as results of corresponding reliability issues seems, therefore, overall little.

Further research should include more potential influencing factors to explain these highly individual, non-systematic responses better. Possibly, significant changes might be more visible in gait.

CONCLUSION

The inconsistent influences of unilateral trunk muscle fatigue on pelvic position show the complexity and individuality of muscular involvement.

AUTHOR CONTRIBUTIONS

Bartaguiz, Dindorf, conceived and designed the experiments; Bartaguiz, Janowicz performed the experiments; Dindorf and Fröhlich analysed the data; Fröhlich and Ludwig contributed materials/analysis tools; Bartaguiz, Dindorf, Janowicz, Fröhlich and Ludwig wrote the paper.

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DISCLOSURE STATEMENT

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

ETHICS STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by Technische Universität Kaiserslautern. Informed consent was obtained from all subjects involved in the study.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study. Written informed consent was obtained from the patients to publish this paper.

DATA AVAILABILITY STATEMENT

The data are available if there is justified research interest.

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