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Effects of a wearable device and functional wear on spinal alignment and jump performance

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ABSTRACT

Background/objective: To elucidate the effects of walking exercise using a wearable device and functional wear on spinal alignment and jump performance.**Methods:** In total, 27 female college soccer players were randomly divided into two groups: trunk solution (TS) and compression garments (CGs). Spinal alignment, jump performance, and electromyography activity during the jump performance of the two groups were measured after a 20-min walking exercise. The values for each group were compared t pre- and post-intervention.**Results:** The flexibility of the lower thoracic vertebrae in spinal alignment was increased during extension in the TS group. However, the post-value of the abdominal external oblique muscle during a countermovement jump (CMJ) was significantly lower than its pre-value ($p < 0.05$). In addition, even though spinal alignment was not affected in the CG group, post-values of the jump height during squat jump and CMJ were significantly higher than their pre-values ($p < 0.05$). Furthermore, the post-value of the biceps femoris during the countermovement jump with arm was significantly lower than its pre-value ($p < 0.05$).**Conclusion:** Our study suggested that walking exercise using TS may increase the range of motion of the lower thoracic vertebrae in athletes and reduce the muscular activity of the vastus lateralis during CMJ. Additionally, although spinal alignment is not affected, the jump height may increase using CGs.© 2020 The Society of Chinese Scholars on Exercise Physiology and Fitness. Published by Elsevier (Singapore) Pte Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Trunk training has gained attention in various sports and medical settings. The optimal function of the trunk muscles is to increase trunk stability and muscle coordination and to theoretically reduce the risk of injuries.^{1,2} Studies on trunk muscle stability often focus on functions of deep muscles, such as the transversus abdominis^{3–5} and multifidus muscle,^{6,7} and superficial muscles, such as the rectus abdominis, abdominal external oblique muscle, and erector spinae. These superficial muscles have been shown to

affect jump performance during exercise due to their role in trunk stability and involvement in the movement of the upper and lower limbs.^{8–11}

Recently, development and clinical research of orthoses-related postures and trunk muscle groups have been primarily conducted in the medical field.^{12–18} Furthermore, a trunk orthosis that alleviates mechanical burden on the lumbar region while increasing trunk stability (TORF; Trunk Solution Co., Ltd, Tokyo, Japan, hereinafter referred to as TS) has been developed.^{19–23} This device has a joint equipment with a resistive force that applies a mechanical force to the front of the sternum. Moreover, TS has been clarified to promote contraction of deep trunk muscle groups and has a positive effect on stabilizing the trunk and pelvic girdle.^{20–23} Previous studies using TS have shown significant improvement in the walking speed and stride after removing the core brace as well as after adjusting the core alignment when used in patients with

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stroke.²¹ Conversely, various functional wears are being sold to improve exercise and physical functions. Compression garments (CGs) provide stability and support to the body by applying mechanical pressure on the body surface.²⁴ Additionally, CGs have been reportedly effective in improving runners' endurance performance and alleviating delayed-onset muscle soreness and fatigue.^{25,26}

However, no previous studies have compared jump performance using TS and CGs. Although effects of TS in healthy adult men and elderly people have been verified,^{19,22} no study has determined the effects of TS in female athletes. An investigation on the effects of TS and CGs, expected to improve spinal alignment and enhance trunk stability, in athletes may help improve the performance of athletes.

This study aimed to determine the effects of walking exercise using TS and CGs on spinal alignment and jump performance. We hypothesize that wearing TS increases trunk stability, promotes pelvic anteversion, and improves jump performance more significantly as compared with wearing CGs.

Methods

Participants

This study included 27 female college soccer players from the second division of the Kanto University Women's Soccer League with regular exercise habits of >5 days a week (Table 1). Participants who could perform the research protocol and without problems in wearing the device are included. All participants did not have a history of upper or lower limb injury, including low back pain and sacroiliac joint pain in the last 3 weeks. Exclusion criteria were as follows: those with injury in the upper limbs, trunk, and lower limbs during the last 3 weeks, history of fracture in the last 6 months, or restricted to participate in physical activities by a doctor. Prior to measurements, objectives and content of measurements as well as expected pains and risks during measurements were thoroughly explained in both oral and written forms to participants, and then informed consent was obtained. The privacy right of human participants was observed. This study was approved by the Research Ethics Committee of the Graduate School of Health and Sports Science, Juntendo University (Number: 30-124). The work described has been carried out under the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Experimental design

Fig. 2 shows an overview of the experimental procedure. Each experimental day is started by measuring the body composition of participants using In Body (730 Body Composition Analysis). Then, based on the previous research, participants walked (6 km/h) on the treadmill for 5 min²⁷ as a warm-up (W-up) exercise. After the W-up, spinal alignment was measured, and each of the jump test items, i.e., squat jump (SJ), countermovement jump (CMJ), and countermovement jump with arm (CMJWA), were performed three times each. During the jump test measurements, the activity of five test muscles, namely, the vastus lateralis, long head of biceps

Table 1
Body composition of participants and comparison between groups.

| Group | N | Age (years) | Height (cm) | Weight (kg) | BMI |
|-------|----|-------------|-------------|-------------|------------|
| All | 27 | 20.0 ± 0.9 | 160.3 ± 5.7 | 56.0 ± 6.7 | 21.7 ± 2.0 |
| TS | 13 | 19.8 ± 0.8 | 160.5 ± 5.8 | 58.5 ± 7.0 | 22.7 ± 1.7 |
| CG | 14 | 20.1 ± 1.0 | 160.2 ± 5.8 | 53.7 ± 5.6 | 20.9 ± 1.9 |

BMI, body mass index; CG, compression garment; TS, trunk solution.

femoris, erector spinae, rectus abdominis, and abdominal external oblique muscle, were measured via electromyography (EMG) (Telemetry 2400R G2 telemetry system: Noraxon USA Inc., Scottsdale, Arizona, USA). Then, the TS group wore the brace, whereas the CG group wore the functional wear, and then all of them walked on the treadmill at 6 km/h for 20 min.²⁸ The orthosis used in this study was reported to exert its effect on walking even after removal; therefore, walking exercise was performed as an intervention.^{19,22} The orthosis and CG wearing time were <1 min, and the brace wearing was performed as specified. After walking, spinal alignment, jump tests, and EMG of participants during jump tests were measured using the procedure described above.

The study design was a randomized controlled trial. This study was conducted for approximately a month from mid-February to mid-March 2019. Participants were randomly classified into two groups using a computer: TS and CG (Table 1). All experiments (trials) were conducted indoors at a temperature of 20 °C and humidity of 50%.

Spinal alignment

The device used in this study (Trunk Solution?R?R: TS, Trunk Solution Corporation, Japan) was a brace-type wearable device equipped with joints that provide resistive force (Fig. 1). This force promotes deep trunk muscle contraction by applying joint force to the front of the chest, resulting in trunk, and pelvic stability.

The CGs used was a compression wear (Under Armour, Inc. Baltimore, Maryland, USA). Participants were provided the compression wear according to manufacturer's guidelines. Compression wear is elastic, fits the body, and is innerwear worn by competitive athletes during competition.

Measurements of spinal alignment were based on previous studies.²⁹ To measure the spinal alignment, the angle of 17 movable parts from between the first and second thoracic vertebrae (Th1/2) to between the fifth lumbar vertebra and first sacral vertebra (L5/S1) was measured in three postures, upright, flexion, and extension positions, in the sagittal plane using a rachimeter (Spinal Mouse™, Idiag AG, Switzerland). Four measurement items were thoracic vertebrae (Th1–Th12), lower thoracic vertebrae (Th9–Th12), lumbar vertebrae (Th12–S1), and sacral slope. Participants were instructed to remove their shoes and spread their legs up to the shoulder width. Then, spinal alignment was determined from the previously marked seventh cervical vertebra to the sacral vertebra in alignment with the baseline of the body. The obtained data were evaluated using the accessory software of the Spinal Mouse™ (Spinal Mouse R, Version3.32, Idiag AG, Switzerland).

Jump performance

Mat Switch (DKH Co., Ltd. Tokyo, Japan) was used to measure the results of jump tests. In each jump test, three jumps, namely, SJ, CMJ, and CMJWA, were performed.³⁰ Each test was performed thrice at pre- and post-interventions, respectively, and the highest jumped height was recorded. An approximately 10-s rest was provided between each jump test, and the jump was performed at the participant's timing. Data were analyzed using the Multi-Jump Tester, a specialized software for jump measurement.

Electromyography activity

Silver/silver chloride surface electrodes (Ambu Blue Sensor P, Ambu A/S, Denmark) with a diameter of 9 mm were set to measure EMG activity during jump. Referring to the method described by Sakamoto et al.,³¹ the activity of five test muscles, namely, vastus

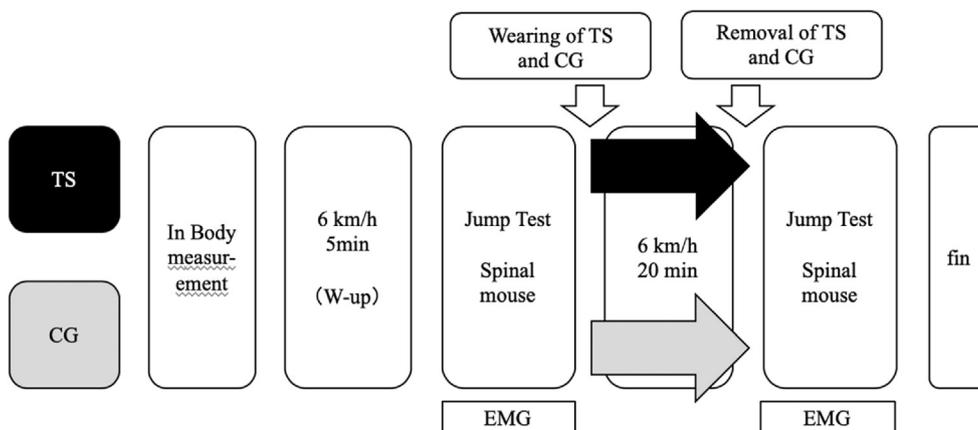


Fig. 1. Appearance of the trunk orthosis.

lateralis, long head of biceps femoris, rectus abdominis, abdominal external oblique muscle, and erector spinae, was determined. Participants were instructed to remove body hair in advance. After wiping the skin surface with alcohol for skin cleansing, body hair was shaved using Skin Pure. The skin–electrode distance was set at approximately 30 mm. Impedance was <math><5 \Omega</math> for all test muscles. EMG signals were amplified using the Telemyo 2400R G2 telemetry system (Noraxon USA Inc., Scottsdale, Arizona, USA) with high- and low-pass filters set at 10 and 500 Hz, respectively. Data were collected at 1500 Hz and 16 bit resolution using a personal computer installed with an auxiliary software. Data were obtained after the root mean square treatment.

Statistical methods

All statistical analyses were performed using a statistical analysis software (IBM SPSS Statistics Version 22). Pre- and post-values of each measurement item are presented as mean \pm standard deviation. Unpaired *t*-test (Student *t*-test) was used for the baseline comparison of TS and CG groups. Paired *t*-test was used to compare pre- and post-values of spinal alignment, jump height, and EMG activity during the jump performance between TS and CG groups. The *t*-test was used to compare changes in the TS and CG groups. Cohen’s *d* was used to determine the effect size. Values set for the particular effect size, such as 0.2, 0.5, and 0.8 are small, moderate, and large, respectively. The statistical significance level was set to $p < 0.05$.

Results

Regarding baseline

Table 2 presents the results of the baseline comparison of participants. No significant differences were observed in the spinal alignment and jump height of baseline measurements between TS and CG groups. However, the EMG activity of the abdominal external oblique muscle during SJ ($p = 0.002, d = 1.34$), abdominal external oblique muscle during CMJ ($p = 0.007, d = 0.52$), and abdominal external oblique muscle and rectus abdominis during CMJWA in the CG group ($p = 0.029, d = 0.42, p = 0.024, d = 0.43$) were significantly higher than those in the TS group.

Tables 3–5 show a comparison of changes in TS and CG groups. When comparing changes in TS and CG groups, a significant difference was observed only in the abdominal external oblique muscle during CMJWA between the TS (-2.5 ± 30.0) and CG groups (-15.9 ± 36.4) ($p = 0.042, d = 0.39$) (Table 3). Moreover, the amount of change in the lower thoracic vertebra during extension in the TS group tended to increase ($p = 0.061, d = 0.76$) (Table 4), whereas the amount of change in SJ and CMJ in the TS group tended to decrease ($p = 0.065, d = 0.77, p = 0.071, d = 0.78$) (Table 5), and no significant difference was observed.

Discussion

This study examined the effects of walking exercise using a TS and CG on the spinal alignment and jump performance of 27 female college soccer players. According to the results, the flexibility of the lower thoracic vertebrae in spinal alignment was enhanced during extension, and the post-value of abdominal external oblique



Fig. 2. The experimental design.

Table 2
Baseline comparison between the two groups based on spinal alignment, jump height, and electromyography of muscle activity at pre-intervention.

| | TS | CG | P-value | d |
|-----------------------------------|---------------|---------------|---------|------|
| Spinal Alignment | | | | |
| Upright Position | | | | |
| Thoracic Vertebrae | 43.6 ± 8.2 | 39.9 ± 7.9 | 0.245 | 0.46 |
| Lower Thoracic Vertebrae | 4.0 ± 5.6 | 3.3 ± 4.9 | 0.725 | 0.13 |
| Lumbar Vertebrae | -25.9 ± 3.9 | -25.9 ± 7.3 | 0.981 | 0.01 |
| Sacral Slope | 14.8 ± 4.6 | 14.6 ± 6.7 | 0.903 | 0.03 |
| Flexion | | | | |
| Thoracic Vertebrae | 57.7 ± 11.5 | 57.6 ± 8.7 | 0.976 | 0.01 |
| Lower Thoracic Vertebrae | 17.0 ± 5.0 | 16.6 ± 6.5 | 0.875 | 0.07 |
| Lumbar Vertebrae | 23.8 ± 10.0 | 23.4 ± 10.6 | 0.903 | 0.04 |
| Sacral Slope | 60.0 ± 20.5 | 61.1 ± 18.1 | 0.887 | 0.06 |
| Extension | | | | |
| Thoracic Vertebrae | 47.5 ± 15.5 | 47.5 ± 9.4 | 0.994 | 2.36 |
| Lower Thoracic Vertebrae | 3.7 ± .6 | 3.2 ± 9.3 | 0.903 | 0.02 |
| Lumbar Vertebrae | -37.5 ± 5.8 | -40.8 ± 15.5 | 0.206 | 0.24 |
| Sacral Slope | -9.5 ± 10.1 | -13.9 ± 14.8 | 0.388 | 0.34 |
| Jump test | | | | |
| SJ | 24.5 ± 3.4 | 24.0 ± 4.2 | 0.745 | 0.13 |
| CMJ | 25.7 ± 3.8 | 25.1 ± 4.0 | 0.678 | 0.15 |
| CMJWA | 30.0 ± 4.4 | 30.3 ± 4.7 | 0.866 | 0.07 |
| EMG | | | | |
| SJ | | | | |
| Vastus Lateralis | 280.6 ± 52.7 | 242.0 ± 71.9 | 0.127 | 0.61 |
| Biceps Femoris | 115.3 ± 34.6 | 132.3 ± 42.7 | 0.268 | 0.44 |
| Abdominal External Oblique Muscle | 55.9 ± 20.0 | 92.6 ± 32.9 | 0.002** | 1.34 |
| Rectus Abdominis | 71.3 ± 43.0 | 147.3 ± 145.5 | 0.357 | 0.18 |
| Erector Spinae | 163.6 ± 38.5 | 202.1 ± 66.4 | 0.080 | 0.70 |
| CMJ | | | | |
| Vastus Lateralis | 341.0 ± 88.4 | 306.8 ± 79.8 | 0.299 | 0.41 |
| Biceps Femoris | 156.3 ± 42.4 | 160.8 ± 47.3 | 0.797 | 0.10 |
| Abdominal External Oblique Muscle | 76.6 ± 25.4 | 125.7 ± 54.1 | 0.007* | 0.52 |
| Rectus Abdominis | 98.4 ± 89.7 | 205.3 ± 304.9 | 0.174 | 0.26 |
| Erector Spinae | 202.7 ± 71.1 | 212.4 ± 74.5 | 0.734 | 0.13 |
| CMJWA | | | | |
| Vastus Lateralis | 356.8 ± 126.2 | 301.4 ± 68.8 | 0.244 | 0.22 |
| Biceps Femoris | 164.2 ± 92.9 | 175.0 ± 69.0 | 0.733 | 0.13 |
| Abdominal External Oblique Muscle | 113.5 ± 76.9 | 141.8 ± 42.5 | 0.029* | 0.42 |
| Rectus Abdominis | 105.4 ± 59.0 | 318.9 ± 346.0 | 0.024* | 0.43 |
| Erector Spinae | 191.3 ± 49.5 | 217.5 ± 73.8 | 0.293 | 0.41 |

*Significant difference between groups (p < 0.05).

**Significant difference between groups (p < 0.01).

CG, compression garment; CMJ, countermovement jump; CMJWA, countermovement jump with arm; EMG, electromyography; SJ, squat jump; TS, trunk solution.

Table 3
Comparison of changes in the muscle activity during each jump test.

| | TS | CG | P-value | d |
|-----------------------------------|--------------|---------------|---------|------|
| EMG | | | | |
| SJ | | | | |
| Vastus Lateralis | -3.1 ± 64.7 | -8.4 ± 37.0 | 0.794 | 0.10 |
| Biceps Femoris | -5.4 ± 41.4 | -9.0 ± 25.2 | 0.789 | 0.11 |
| Abdominal External Oblique Muscle | 0.0 ± 17.4 | -1.2 ± 51.6 | 0.940 | 0.03 |
| Rectus Abdominis | -10.6 ± 24.7 | -48.2 ± 140.2 | 0.560 | 0.11 |
| Erector Spinae | -25.6 ± 52.9 | -5.7 ± 40.8 | 0.382 | 0.17 |
| CMJ | | | | |
| Vastus Lateralis | 10.3 ± 34.6 | -22.4 ± 49.3 | 0.059 | 0.76 |
| Biceps Femoris | -14.1 ± 26.5 | -13.9 ± 29.8 | 0.981 | 0.01 |
| Abdominal External Oblique Muscle | -14.8 ± 22.2 | -14.7 ± 41.4 | 0.989 | 0.00 |
| Rectus Abdominis | -11.3 ± 23.3 | -71.5 ± 318.1 | 0.662 | 0.08 |
| Erector Spinae | -43.5 ± 88.1 | -5.1 ± 44.6 | 0.162 | 0.56 |
| CMJWA | | | | |
| Vastus Lateralis | -13.9 ± 57.0 | -9.2 ± 48.6 | 0.819 | 0.09 |
| Biceps Femoris | -25.0 ± 70.1 | -27.1 ± 43.9 | 0.926 | 0.04 |
| Abdominal External Oblique Muscle | -2.5 ± 30.0 | -15.9 ± 36.4 | 0.042* | 0.39 |
| Rectus Abdominis | -1.4 ± 38.4 | -99.9 ± 301.6 | 0.627 | 0.09 |
| Erector Spinae | -28.8 ± 62.9 | -19.3 ± 43.8 | 0.698 | 0.08 |

*Significant difference between the groups (p < 0.05).

CG, compression garment; CMJ, countermovement jump; CMJWA, countermovement jump with arm; SJ, squat jump; TS, trunk solution.

Table 4
Comparison of changes in spinal alignment.

| | TS | CG | P-value | d |
|--------------------------|------------|------------|---------|------|
| Spinal Alignment | | | | |
| Upright Position | | | | |
| Thoracic Vertebrae | -1.8 ± 5.4 | -1.0 ± 5.1 | 0.705 | 0.15 |
| Lower Thoracic Vertebrae | -0.6 ± 3.8 | -0.2 ± 3.7 | 0.783 | 0.11 |
| Lumbar Vertebrae | 2.5 ± 5.9 | -1.4 ± 4.8 | 0.071 | 0.73 |
| Sacral Slope | -0.2 ± 0.0 | 2.5 ± 3.6 | 0.864 | 0.03 |
| Flexion | | | | |
| Thoracic Vertebrae | 0.7 ± 6.9 | 2.0 ± 6.5 | 0.617 | 0.19 |
| Lower Thoracic Vertebrae | 0.4 ± 4.2 | 2.0 ± 4.3 | 0.333 | 0.38 |
| Lumbar Vertebrae | 0.2 ± 4.9 | 0.8 ± 8.4 | 0.816 | 0.09 |
| Sacral Slope | 0.3 ± 6.7 | -0.9 ± 4.8 | 0.582 | 0.21 |
| Extension | | | | |
| Thoracic Vertebrae | 0.5 ± 7.8 | -0.4 ± 5.8 | 0.735 | 0.13 |
| Lower Thoracic Vertebrae | 2.8 ± 4.2 | -0.7 ± 4.9 | 0.061 | 0.76 |
| Lumbar Vertebrae | 1.6 ± 8.2 | -1.9 ± 7.4 | 0.248 | 0.45 |
| Sacral Slope | -1.9 ± 5.6 | -1.8 ± 6.0 | 0.952 | 0.02 |

CGs, compression garment; TS, trunk solution.

Table 5
Comparison of changes in jumps of three jump tests.

| | TS | CG | P-value | d |
|------------------|------------|-----------|---------|------|
| Jump test | | | | |
| SJ | -0.3 ± 1.7 | 0.8 ± 1.1 | 0.065 | 0.77 |
| CMJ | -0.1 ± 1.8 | 1.0 ± 0.9 | 0.071 | 0.78 |
| CMJWA | 0.6 ± 1.6 | 0.3 ± 1.4 | 0.734 | 0.07 |

CG, compression garment; CMJ, countermovement jump; CMJWA, countermovement jump with arm; SJ, squat jump; TS, trunk solution.

muscle during CMJ was significantly lower than the pre-value in the TS group. Although spinal alignment was not affected in the CG group, post-values of the jump height during SJ and CMJ were significantly higher than their pre-values. Furthermore, the post-value of the biceps femoris during CMJWA was significantly lower than its pre-value.

TS group

In the TS group, the post-value of the range of motion of the lower thoracic vertebrae in the spinal alignment during extension was significantly higher than its pre-value. Wearing TS may stabilize the trunk muscle groups and pelvis and increase the range of motion of the lower thoracic vertebrae during extension. In terms of CMJ, TS may activate the trunk muscles, particularly the transversus abdominis, which may also result in decreased activation of the external oblique muscle. In a previous study, wearing a trunk brace (ORF & NDO) on a stroke patient not only reduced the lumbar extension movement but also increased the lumbar flexion movement caused by the abdominal muscle groups but also significantly decreased the trunk flexion angle.^{19,21} Furthermore, the thickness of the transversus abdominis muscle has also been reported to significantly increase by wearing a TS.²³ A study on resting abdominal muscle activity in patients with low back pain showed that weakness and delay of transverse abdominal muscle activity result in excessive muscle activity in the internal and external oblique muscles.³² As described above, the spinal sagittal alignment may be improved and the muscle activity of the transversus abdominis muscle increased in the TS group. As a result, the muscle activity of the external oblique was considered to be decreased.

Next, the jump height of three jump tests in the TS group showed no significant difference when comparing pre- and post-values. The reason for this is that competitive athletes are usually trained. Although TS wearing has an effect on the dynamic

alignment of the spinal column, it may not affect the muscular activity of the lower limbs. Arumugan et al. reported that the pelvic belt was used to measure EMG activity of the hamstrings while walking. They reported no significant change was observed in the hamstring muscle activity.^{33,34} Consistent with this study, the trunk brace might not be suitable for the performance improvement even in movements that require instantaneous muscle exertion of the lower limbs.

CG group

No significant difference was observed in the spinal alignment before and after walking using CGs. Functional wear has been reported to reduce the risk of muscle fatigue and injury by applying pressure to the wear site during training and competition.^{24,35} However, no report has demonstrated that functional wear affected the posture and spinal alignment, and thus, results of this study were considered to have no effect on the spinal alignment of the CG group.

Post-values of the SJ and CMJ were significantly higher than pre-values in walking exercise using CGs. A previous study has reported that functional wear affects the jump performance.³⁶ In addition, functional wear possibly affects suppressing vibrations on the muscles due to pressure exerted on the covered area³⁷ and positively affects fatigue,³⁸ possibly resulting in improved jump performance.³⁹ A study on athletes wearing compression wear reported that the maximum jump height of CMJ was 2.4 cm, which was higher than that of the control group.³⁷ However, these previous studies have not included reports on the positive relationship between jump performance and compression wear.^{39–41}

In the CG group, in addition to the jump height, muscle activity during the jump was also measured using EMG. In EMG during jumping, the post-value of the biceps femoris during CMJWA was significantly lower than its pre-value.

In CMJWA, limiting the flexion angle of the knee is difficult because the action of shaking the arm is added to CMJ. Previous studies have reported that knee affects maximum muscle strength as well as the quadriceps and hamstrings.^{42–45} Furthermore, hip flexion angle and movement pattern in addition to knee joint angle have been reported to influence the muscular activity of the hamstrings.^{46,47} According to a report by Hewett et al., female hamstrings to quadriceps peak torque (H/Q) ratios did not change with an increase in exercise speed of isotropic contraction.⁴⁸ These reports also suggest that the knee joint angle may change with different joint movements of the knee, affecting the decrease in biceps contraction during CMJWA. Moreover, the jump height of CMJWA was not significantly higher in the CG group. The activity of the quadriceps femoris, particularly that of the rectus femoris, a biarticular muscle, may be activated by the 20-min walk.⁴⁹ In this study, we selected the vastus lateralis muscle to evaluate the quadriceps femoris activity; however, the 20-min walk may also activate the activity of the rectus femoris muscle and that the joint torque for knee extension during jumping was improved.

TS and CG groups

In this study, we compared changes in each TS and CG to determine their effects on spinal alignment and jump performance. The only significant difference was found in the abdominal external oblique muscle during CMJWA. The external oblique muscles at the time of CMJWA in TS and CG groups both decreased; however, the TS group showed a smaller decrease. The large decrease in the amount of changes in the CG group is considered to be owing to the high activity of the external oblique muscle during CMJWA in the CG group at the baseline. No significant difference was observed in

pre- and post-values of the muscle activity during CMJWA in both TS and CG groups. Therefore, a statistically significant difference was considered when comparing the changes. From the results of this study, TS wearing is considered to have a positive effect on the spinal alignment of competitive athletes. However, TS wearing may not improve the jump performance. CG did not have a positive effect on spinal alignment but positively affected the jump performance. However, only few previous studies investigated the effects of CG on the jump performance, such as this study.⁵⁰ Using TS for competitive athletes may improve their posture, including spinal alignment. The study participants were female soccer players, but items such as core muscles and posture are important for competitive athletes. Therefore, we believe that effects of trunk orthoses for athletes engaged in other sports and athletes who have a history of low back pain should be verified.

Limitations

This study has four limitations. First, a functional wear was used in the control group. Because items changed in TS and CG differed at pre- and post-comparison, the effect of wearing other than walking was considered to be confirmed. However, this point cannot be considered because we did not have a walking-only group. Second, this study only targeted female soccer players. However, the relationship between spinal alignment and performance in sports other than soccer is also crucial; therefore, data using athletes of various sports as participants should be accumulated in the future. Third, data on spinal alignment and EMG, which are the outcomes of this study, are values before and after wearing in both groups. Therefore, to investigate the influence of TS and CG in more detail, data should be measured while wearing it. Finally, this is the first study that has used a wearable device on athletes; therefore, further studies are necessary to confirm whether this wearable device can provide additional benefits to athletes.

Conclusion

This study aimed to elucidate the effects of walking exercise using TS and CGs on spinal alignment and jump performance. Our findings suggested that walking exercise using TS could have increased the range of motion of the lower thoracic vertebrae of athletes and could have reduced the muscle activity of vastus lateralis during CMJ. In addition, CGs did not affect the dynamic alignment of the spinal column but possibly increased the jump height.

Ethical Consideration

Prior to measurements, we thoroughly explained the subjects the objectives and content of the measurements as well as the expected pains and risks during the measurements in both oral and written forms after which we obtained informed consent. The privacy right of human subjects was observed. This study was approved by the Research Ethics Committee of the Graduate School of Health and Sports Science, Juntendo University (Number: 30-124). The work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

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CRedit authorship contribution statement

Hayato Ikeda: Writing - original draft, Funding acquisition. **Takayuki Miyamori:** Conceptualization, Writing - review & editing. **Junji Katsuhira:** Data curation, Methodology, Resources. **Ryuichi Sawa:** Formal analysis. **Yu Shimasaki:** Resources. **Yuji Takazawa:** Supervision. **Masafumi Yoshimura:** Project administration.

Conflict of interests

JK is a director and shareholder (unlisted) of Trunk Solution Co., Ltd. Trunk Solution Co., Ltd. is not involved in the creation of experimental protocols, data analysis, or interpretation of the results.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2020.10.002>.

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