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The Influence of Insole with Metatarsal Retro-Capital on Posture, Plantar Pressure and Body Segments Positions in Runners

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Abstract

Objectives. The aim of this study was to investigate the effects of orthopaedic soles on the body posture. *Methods*. Forty-eight runners (21 men and 28 women) maintained a standing-up position on both feet with bare feet with neutral soles and orthopedic soles which contained bilaterally a podiatrist element of 3 mm height behind the metatarsal heads (Metatarsal Retro Capital Bar, MRCB). Stabilometric, plantar pressure and kinematic data in the sagittal plane on both sides were measured at 40 and 60 Hz, respectively. The position of the center of pressure on the anteroposterior axis (Y_{CoP}), the forefoot plantar pressure (FPP) and the anteroposterior position of the knee (Y_k), the hip (Y_H), the shoulder (Y_S) and the ears (Y_E) with respect to the vertical axis passing through the joint of the ankle were determined for each experimental condition. *Findings*. The addition of a MRCB orthopedic element induced in backward displacement of CoP, hip, shoulder and ears ($p < 0.01$). Y_{CoP} and FPP changes were significantly correlated with Y_H, Y_S and Y_E changes ($p < 0.01$). *Conclusion*. These results suggest that the addition of an orthopedic element located behind the metatarsal heads influences the overall position of the body and can help podiatrist in the care of their patients.

Keywords

Posture, Pressure, Insoles, Thin Plantar Stimulation, Podiatry

1. Introduction

The postural system which participated to the body balance control, acts like a reversed pendulum around a fixed point located at the ankle [1]. Many mechanoreceptors of the foot's sole participate in the control of the balance [2]. Most of the rapidly adapting Pacini's receptors are located in the front of the foot at the metatarsal heads, whereas the slowly adaptive receptors are mainly located on the medial and lateral sides of the foot. Changes in proprioceptive and mechanical information's on the foot may lead to postural adaptations [3] [4]. General or partial anesthesia of the feet can cause, for example, a displacement of the Center of Pressure (CoP) of the body in the antero-posterior and/or medio-lateral direction while maintaining the standing position [5].

Several studies have investigated the effects of changes in feet sensory input on body posture. Mechanical vibrations applied on the anterior plant of the foot or on the muscles tendons of leg's posterior compartment induced a displacement of CoP to the back [6] [7]. In contrary, a stimulation of the posterior plant of the foot or muscles tendons of the leg's anterior compartment enhanced a CoP displacement towards the front. These results show that the origin of proprioceptive information influences the adaptation of the body to mechanical vibrations. The CoP moves in the same direction of muscular stimulation whereas a plantar stimulation causes a CoP motion to the opposite direction. The resulting cutaneous stimulation gives the body information of an excess of pressure that causes an opposite reaction to release the area. During the stimulation of the forefoot, the soleus was activated initially to move the CoP to the back. The main antagonist muscle, *i.e.*, the tibialis anterior, is then activated to control this movement and prevent the subject from falling back [8].

The use of orthopedic elements under the sole modifies the proprioceptive information from the mechanoreceptors and can cause a displacement of the CoP while maintaining the standing posture. The addition of a 3 mm element under the internal or external part of the plantar arch of one of the two feet moves the CoP to the opposite side [9]. The two-sided placement of this orthopedic element causes the CoP to move to the back [10] and can stabilize postural balance [11]. This change is more important when the two elements are placed on the anterior part of the feet [12], because it contains most fast-acting mechanoreceptors [2], and is comparable to the one observed during stimulation of the anterior plant of the foot by mechanical vibrations [6].

The addition of elements behind the Metatarsal Retro Capital Bar (MRCB) allows to reduce the pressure under the forefoot [13], and thus allows to better distribute it between the forefoot and the rearfoot [14]. Like to cutaneous vibration stimulation, this orthopedic element could have the same effect by increasing the pressure behind the metatarsal heads induce by the relief. If the body reacts in the same way by moving backwards, then the plantar pressure under the feet will be reduced. During running, MRCB elements would help to support the feet at the end of the run where the pressure is more important under the front feet. The main clinical application of this element is the reduction of pressure under the fronts that can be interesting in sport podiatry to reduce the risk of injury in this area [14] and thus decreasing the risk of metatarsal pain or stress fracture [15]. This better distribution could result in a change on the overall body posture, manifested by a displacement in the antero-posterior axis of the overlying's joints. It has been shown that the bilaterally use of orthopedic elements under the sole of the foot induced changes in the position of the ankles, knees, pelvis and trunk joint in the frontal plane, while maintaining standing position on one foot [16] [17] or during walking [18] [19] [20]. Stimulation of the planar sole via vibratory stimulation [6] [8] or podiatry elements [10] [12] influences the globality of the subject by having an effect on the oculomotor muscles [10] especially through the intermediary of the muscular chains [8]. However, to our knowledge, no studies have evaluated the influence of MRCB element on the overall position of the body.

The aim of this study is to evaluate the effects of wearing orthopedic soles equipped with MRCB elements on the position in the sagittal plane of the CoP and of the overlying's joints. We hypothesize that the addition of MRCB elements induce backward movements of the CoP and all overlying's joints while standing position.

2. Methods

2.1. Population

Forty-eight regular runners, practicing minimum twice a week (27 men and 21 women) who had no medical and/or surgical history, during the last five years, took part in this study (33.3 ± 10.2 years, 172 ± 9.9 cm, 66.8 ± 15.9 kg). After being orally informed and in writing of the experimental protocol, all the participants signed the consent form in accordance with the Helsinki declaration on biomedical research.

2.2. Stabilometric and Plantar Pressure Measurements

The position of the CoP and the plantar pressure under each foot were measured at a sampling frequency of 40 Hz by a Fusyo stabilometric platform (Medicapteurs®, Balma, France).

The average position on the antero-posterior axis of the global CoP (Y_{CoP}) and of the CoP under right foot (Y_{RF}) and left foot (Y_{LF}) were measured in cm with respect to platform point of reference (O, X, Y). Data were analyzed by Fusyo Software (Medicapteurs®, Balma, France).

The average forefoot plantar pressure (FPP) under each foot was calculated for each experimental condition. The median line of the feet, dividing forward and backward, is calculated as half the distance between the most anterior and posterior points of each foot. The values on both sides were averaged and expressed as a percentage of body weight.

2.3. Kinetics Parameters

The positions on the sagittal plane of the joints of the knee, hip, shoulder and the head were recorded on either side by two High-Definition cameras (image resolution: 1290 × 1080 pixels; Go Pro Hero 4®, San Mateo, USA) at a frequency of 60 Hz. The cameras were placed on each side, one meter from the platform, in the extension of its center, and raised from the ground by one meter. The synchronization between the data of the platform and the cameras was allowed by a light diode placed on the platform and visible from the cameras. The joints centers were previously identified and marked by circular black adhesive circles of 12 mm diameter placed for the ankle, on the lateral malleolus; for the knee, at the level of the lateral tuberosity of the lateral femoral epicondylus; for the hip, on the femoral's greater trochanter; for the shoulder, on the major tubercles humeral; and for the head, on the tragus of the ears.

The kinematic data were processed by the Kinovea® software (version 0.8.24). The anterior-posterior position of the knee joint (Y_K), the hips (Y_H), the shoulders (Y_S) and the head (Y_E) were measured in cm with respect to the axis passing through the lateral malleolus. The values on both sides were averaged.

2.4. Plantar Stimulation

The orthopedic soles of each subject contained a MRCB element of 3 mm thickness made of Ethyl Vinyl Acetate (EVA) of hardness 70 shore A (Eloi, Nogent-sur-Marne, France). These elements were placed behind the metatarsal heads by an experienced podiatrist as a function of the individual footprint [12] [21].

2.5. Procedure

The participants were placed barefoot onplatform. Feet were oriented on either side of the transverse axis of the platform at an angle of 30˚, the heels separated of 4 cm and the patients were positioned facing a wall at a distance of 90 cm. The runners had to remain as immobile as possible for 51.2 seconds. Satbilometric, plantar pressure and kinematic were synchronize and collected during this time. Parameters were collected in two sensory conditions: in neutral condition using normal soles (N)) and with podiatric stimulation (MRCB condition).

After one passage of accommodation, the subjects made one passage by condition. The two conditions were randomized for all the participants and separated by one minute of passive recovery.

2.6. Statistical Analysis

Since all data (stabilometric, plantar pressure and kinematic on each side) did not follow the normal distribution (Shapiro-Wilk). The effect of the use of orthopedic soles on stabilometric (Y_{CoP}, Y_{RF}, Y_{LF}), plantar pressure and kinematics variables (Y_K, Y_H, Y_S, Y_E) was tested using the nonparametric Wilcoxon test performed on rows. Spearman test was used to determine the degree of linear relationship between the stabilometric, plantar pressure and kinematic variables. The level of significance for all tests was set to $p < 0.05$.

3. Results

Statistical analysis shows a significant backward displacement 20% of global CoP in the MRCB condition relative to the control condition ($p < 0.01$) (Figure 1(a)). However, no significant differences have been found between the position of CoP of each foot (Y_{RF}, Y_{RL}). FPP was 15% lower in the MRCB condition than in the control condition ($p < 0.01$) (Figure 1(b)).

The anteroposterior position of the hip (Y_H), the shoulder (Y_S) and the head (Y_E) in relation to the ankle joint was significantly reduced with the use of the orthopedic soles by 9%, 11% and 7% respectively ($p < 0.01$) (Figure 2). The anteroposterior position of the knee was not significantly different between the two experimental conditions.

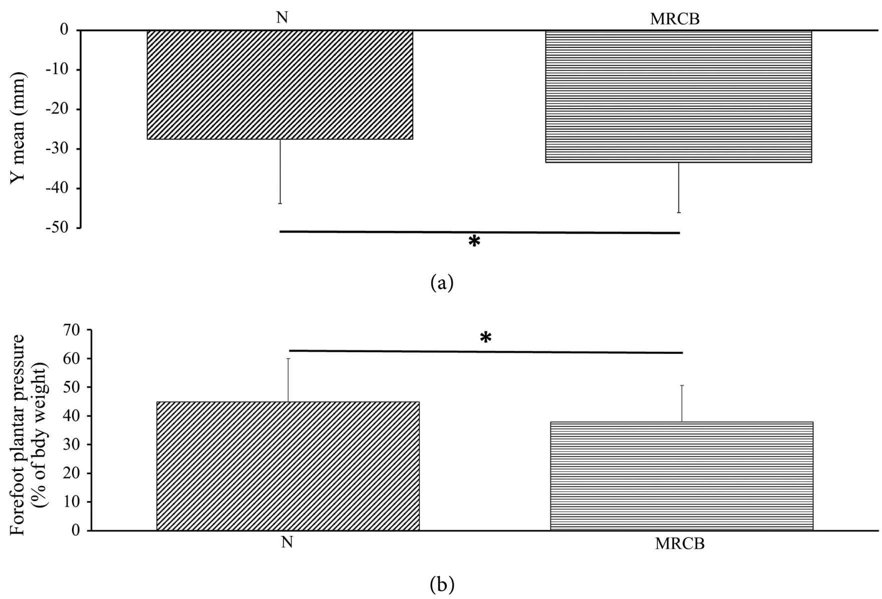

Figure 1. Average position of the COP (a) and plantar pressure under the forefoot (b) with the wearing of the neutral sole (N) and the orthopaedic sole (MRCB) (*: $p < 0.01$).

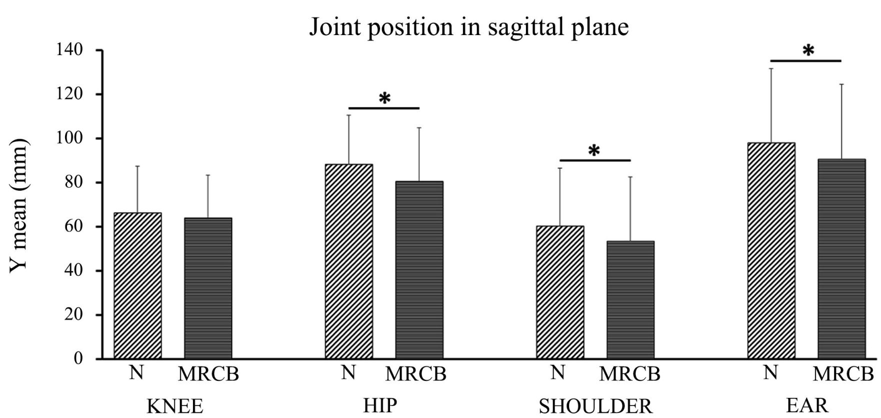

Figure 2. Position of the joints of the knee, hip, shoulder and head with respect to the ankle in the sagittal plane with the wearing of the neutral sole (N) and the orthopaedic sole (MRCB) (*: $p < 0.01$).

Spearman tests revealed a weak relationship between FPP and Y_E ($r = 0.47$, $p < 0.01$); moderate relationships between Y_{COP} and Y_E ($r = 0.61$, $p < 0.01$), between Y_{CoP} and Y_S ($r = 0.67$; $p < 0.01$), between Y_{CoP} and FPP ($r = 0.69$, $p < 0.01$), between FPP and Y_S ($r = 0.70$, $p < 0.01$), between FPP and Y_H ($R = 0.72$, $p < 0.01$); and a strong relationship between Y_{COP} and Y_H ($r = 0.85$, $p < 0.01$). The link between the other variables was not significant.

4. Discussion

The aim of this study was to evaluate the effect of orthopedic elements placed behind the metatarsal heads (MRCB) on the displacement of the center of pressure and on the anteroposterior position of joints overlying the ankle while maintaining the standing posture. Our results showed that the bilaterally use of MRCB elements induces significant backward displacement of the center of pressure and of hip, shoulder and head joints without having any influence on the knee. A decrease a forefoot plantar pression with MRCB is also shown in this study.

Thus this result completes the previous study who found the same results on plantar pressures with vibration [6] and with a podiatric wedge [10] [12] [14]. Thus, the work of the MRCB increases the pressure behind the metatarsal heads thus simulating for the body an earlier imbalance that it seeks to compensate backwards. This conclusion is similar to the vibration tests performed by Kavounoudias *et al.* [6] where the previous vibration's stimulation simulated an excess of pressure in this area. The body replaces its segments to the rear causing a decline in CoP and decreasing the plantar pressures under the front feet.

The backward displacement of the CoP was also observed after vibration's stimulation of the anterior part of the foot [8], and was ever reported with the use of MRCB elements [12]. The backward movement of the pelvic, scapular and head belts observed with the MRCB elements are agree with the reversed pendulum mechanism described previously [1] but without effects to the knee, showing its ability to adapt between the ankle and hip, essential in most sports activities.

However, most podiatrist recommend increasing the height of the heel to decrease the work of the posterior muscle chain. Our results differ somewhat from this theoretical concept since the addition of a MRBC element under the anterior part of the foot seems to decrease the activity this muscular chain regard to the backward displacement of the hip, shoulder joints and head. The effects of this sole's element show here a posterior displacement of the center of pressure, which during the maintenance of the upright posture modifies the point of application of the force while creating a posterior displacement of the hip, the shoulders and the head decreasing the work of the posterior muscle chain. If the knee does not move with respect to the flat sole, while the entire upper part moves backwards, shows that he has undergone some adaptation (flessum?) giving him some freedom. Thus, if the hip goes backwards and the knee does not move with respect to the axis of the camera, this suggests that it undergoes a different angulation that can be at the origin of a flessum of adaptation. However, this decline in the hip, does not cause a change in the knee that keeps a possible adaptation between the ankle and hip. The freedom left to the knee is a key element of this study especially in the sport where it is a factor of absorption and adaptability.

The overall backward body displacement when using MRCB insoles results in a significant decrease in plantar pressure under the forefoot. Moreover, the reduction of the plantar pressure is correlated with the displacement of the hip, the shoulder and the head. Similar correlations between plantar pressure and the positions of the ankle and knee during the use of external element have been also observed in dynamic walking conditions [20]. The work of the knee in the sagittal plane with a MRCB type element induces low intensity movements (Genu flessum and recurvatum) more in connection with an adaptation between the ankle and the hip.

4.1. Practical Application

According to our results, the use of MRCB orthopedic soles seems to be interesting for persons who suffer from recurrent metatarsal pain such as diabetic patients, but also for the elderly who are more prone to the risk of falling forward [22]. Foot injuries, including stress fractures of the metatarsal heads, represent a large part (15%) of the all injuries observed after a long distance running race, *i.e.* a marathon [15] [23] [24]. The appearance of these injuries is seeming to be related to the increase of the ground reaction force under the front feet. Previous studies showed that the plantar pressure under the forefoot increased after a running race [15] [25] or after an exhaustive laboratory running exercise [24] [26] [27]. During running, this element would reduce the zones of pressure under the forefoot that are more important at the end of marathon and could limit injury such as metatarsal pain and stress fracture [15]. This element can be used in prevention or treatment in all people who remain standing for a long time in static (military, factory operator, …) or who moves a lot daily (postman, waiter, …) for work and who may have sore feet. The daily use of this type of orthopedic soles would allow to continue the patient treatment over the long term, which is reduced or mostly stopped after the classic program of functional rehabilitation used in physiotherapy.

4.2. Limits of the Study, Perspectives, Conclusion

Results of this study must be interpreted with caution because they have been obtained in a static position, whereas humans being spend majority of daily time moving and walking. Moreover, data were analyzed only in the sagittal plane. We used a simple protocol to get as close as possible to observations made during a podiatry consultation. Thus, in the future we could do a 3D analysis of the foot to note if this element modifies its structure, especially in dynamics. Some studies shown that bilateral internal orthopedic elements could reduce the ankle adduction moment, knee and hip [17] [18] [19] [20], which may be relevant in the context of osteoarthritic diseases [17] or in the patellofemoral syndromes [18]. Therefore, it would be interesting to evaluate the effect of MRCB elements on plantar pressures and positions of knee, hip, shoulder and head joints during walking and running. Future studies should to measure the electromyography activity of the muscles of the anterior and posterior body chains in order to quantify their work when using MRCB elements.

5. Conclusion

To conclude, this study has shown that the addition of orthopedic elements placed behind the metatarsal heads under each foot results in backward movements of the center of pressure and the overlying ankle joints, except the knee. These changes induced a lower plantar pressure under the forefoot. This orthopedic tool could have an impact on rehabilitation and muscular work from a medical point of view in sports performance.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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