UNIVERSITY OF GOTHENBURG

DEPARTMENT OF FOOD AND NUTRITION, AND SPORT SCIENCE

Comparison of static stance balance between habitual barefoot shoe wearers and conventional shoe wearers: A pilot study

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Bachelor's thesis 15 hp
Health promotion program, sports science
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Abstract

Barefoot living people have better balance and stronger, healthier feet compared to conventional shoe wearing people. Among minimalist shoes, the barefoot shoe allows the foot, in many regards, to behave in a similar way as in a barefoot state, and shows positive effects on foot form and muscle activity. However, when it comes to balance, which is important for the prevention of injury and falls, it is unclear whether barefoot shoe wearers have better balance. The aim of this study was to investigate whether static stance balance differs between habitual barefoot shoe wearers and wearers of conventional shoes. Healthy habitual barefoot shoe wearers (n=14) and conventional shoe wearers (n=27) were recruited in the southwest of Sweden to perform the Unipedal Stance Test (UPST) with shoes and barefoot, of which one test blindfolded and one with eyes open. The groups were matched for age and physical activity level. The barefoot shoe group showed significantly better balance in the eyes open test with shoes ($p<0.01$) as well as the eyes open test while barefoot ($p<0.05$). However, no significant differences were found for the blindfold tests. This preliminary data indicates a better stance balance among barefoot shoe wearers, and that the barefoot shoe may be the better shoe for static stance balance.

Sammanfattning

De som lever barfota har bättre balans och deras fötter är starkare och mer hälsosamma än de som lever i konventionella skor. Inom kategorin minimalistiska skor, tillåter den s.k barfotaskon foten att agera på ett liknande sätt som barfota. Skorna visar också positiva effekter på fotens form och muskelaktivitet. Men när det kommer till balans, något som är viktigt för skadeprevention och preventionen av fall, är det oklart om barfotaskoanvändare har bättre balans. Syftet med denna studien var att jämföra om den statiska balansen skiljer sig mellan de som är vana barfotaskoanvändare och de som lever i konventionella skor. Friska, vana barfotaskoanvändare (n=14) och konventionella skoanvändare (n=27) rekryterades i sydvästra Sverige i syfte att utföra Unipedal Stance Test (UPST) med skor och barfota, varav ett med ögonbindel och ett med öppna ögon. Grupperna matchades med ålder och fysisk aktivitetsnivå. Barfotaskogruppen visade signifikant bättre balans i testerna med öppna ögon med skor på ($p<0.01$), likaså med ögon öppna och utan skor ($p<0.05$). Det var dock ingen statistisk skillnad mellan grupperna i någon av testerna med ögonbindel. Denna preliminära data tyder på bättre balans bland barfotaskoanvändare och att barfotaskon är en bättre sko för statisk balans.

Preface

Authors' contributions

Task assignments	Percent carried out by Anna-Karin/Anton/Adam
Planning of study	33/33/33
Search of literature	45/45/10
Data collection	30/40/30
Data analysis	15/55/30
Writing	40/40/20
Layout	30/55/15

Table of contents

Abbreviations

BO - Barefoot Open

BB - Barefoot Blind

PA - Physical Activity

ROM - Range of Motion

SB - Shod Blind

SO - Shod Open

SSB - Static Stance Balance

S.d. - Standard deviation

UPST - Unipedal Stance Test

Definitions

Barefoot shoe - Refers to a shoe with a thin sole with zero drop and a wider toe box

Five fingers - A type of barefoot shoe which has visible individual sections for the toes

Hallux - The great toe

Hallux valgus - Deformity with an inward angulation of the great toe and an outward angulation of the metatarsal head

Minimalist shoes - A shoe with a flexible sole with little cushioning, no arch support, an upper that weighs 200 g or less, a heel-toe differential of no more than 7 mm and a heel stack of 20 mm or less

Morphology - The shape of an organism or part thereof

Shod - *Adj.* Wearing of shoes

Sway - Shift of center of gravity while attempting to stand still

Toe box - The space at the front part of the shoes that surrounds the toes

Toe spring - The upslant at the front of the shoe

Varus - Outward angle

Zero drop - Denotes no difference in height between the heel and the forefoot of the shoe

Introduction

The foot developed and adapted naturally long before the use of modern footwear (D'AoÛt, Pataky, de Clercq, & Aerts, 2009). For generations, people have been wearing shoes during their daily activities, which has led to both anatomical as well as functional adaptations of the foot.

This has led to foot problems and injuries. Several studies have researched the anatomical adaptations of the foot due to shoe wear.

The bare foot

Habitual barefoot people have a high forefoot spread under load and significantly wider feet than shod people (D'AoÛt et al., 2009; Hoffman, 1905). The effect of these differences are lower peak plantar-pressure among the habitual barefoot people compared to shod people (D'AoÛt et al., 2009). When Hoffman (1905) studied individuals that had never worn footwear, he noticed that in an undistorted foot the phalanges are in line with their metatarsals, the toes are spreaded and separate from each other and thus widen the base under load. The great toe was even more separated from the other toes and served as an important factor in leverage. The role of the wider forefoot and spreaded toes could be a foundation for natural balance control and one of the reasons why barefoot children and adolescents have better balance than their shod counterparts (Zech et al., 2018).

The natural unrestricted foot is mobile and flexible. Aibast et al. (2017) showed that barefoot adolescents have a lower injury prevalence, better foot structure and general foot health compared to shod teenagers. When the foot becomes restricted by the wearing of shoes the foot form becomes altered and anatomical adaptations develop (Sim-Fook & Hodgson, 1958). Narrow, stiff-soled shoes have an effect on the development of foot deformities, such as hallux valgus, hammer toe and bunionettes as well as flat foot (Mafart, 2007; Frey, Thompson, Smith, Sanders, & Horstman, 1993; Holowka, Wallace, & Lieberman, 2018). In a survey of 356 women, 76% of the women studied had at least one foot deformity and 88% wore shoes that were narrower than their feet (on average 1.2 cm smaller) (Frey et al., 1993). Shoes with raised heels force the body to tilt forward. To compensate for the incline, the knees, hip, spine and head need to constantly adjust to retain the body's alignment. Long periods of exposure to this stimulus can cause chronic pain in the legs, back and shoulders (Rossi, 1999). Further, the elevated heel of the conventional shoes draws the heel and ball closer together and shortens the plantar fascia which is related to plantar fasciitis. Other adaptations connected to the elevated heel are shortening of the calf muscle and the achilles tendon which can lead to acute pull of the tendon (Rossi, 2001).

Hoffman (1905) also describes previous habitual barefoot children whose morphology changed with only a few weeks of shoe wearing, with a narrowing of the toes, including a change in direction of the great toe. One boy showed advanced foot changes from wearing shoes after a few short months; which is alarming and could be explained with more compliance due to the plasticity of the growing foot. Hoffman (1905) considered the painless compression made by the wedged toe box of the shoe the reason for these changes. To put the feet in shoes that do not respect the barefoot shape does not cause immediate pain or severe discomfort and could be one reason why people began with and still use footwear that interfere with the anatomy of the foot. Another reason could be the footwear industry. There has not been any other options (until relatively recently) on the market to provide shoes that respect, to a higher degree, the shape and function of the foot.

Besides anatomical adaptations, functional adaptations of the foot due to shoe wear have been researched. Shoes that do not allow the natural foot function also alter the biomechanical behavior of the foot (D'AoÛt et al., 2009). In conventional shoes there is a space between the toe tip and the ground, the upslant at the front of the shoe, called the toe spring. The slant places the toes at a constant upward angle and works as a rolling motion as a compensation for the natural foot-flexing and toe-grasping step (Rossi, 2002). Stiff, inflexible shoes also affect the correct flexion at the ball of the foot, making the flexion occur behind the metatarsophalangeal joints instead of at the joint as it should. This forces the gait to be more flat-footed at push off. Upon taking a step, the bare foot flexes 55°. When wearing shoes, this angle is reduced to 25°, which in turn creates flex resistance and loss of elasticity in the foot (Rossi, 1999).

A functional benefit from barefoot running is the deflection of the medial longitudinal arch on loading, an inherent function of barefoot activity that helps prevent injury in habitual barefoot populations (Robbins & Hanna, 1987). Robbins and Hanna (1987) hypothesise that the foot's sensory feedback is related to the deflection of the arch and argue the sensory isolation in conventional shoes appears responsible for running related injuries. Interestingly, a recent study shows that callus thickness does not affect tactile sensitivity during barefoot walking nor does it affect how hard the feet strike the ground. Even if the sole of the foot thickens and hardens from this kind of barefoot activity, it maintains the ability to perceive tactile stimulus whereas shoes remove this stimulus (Holowka et al., 2019). Further, the occurrence of forefoot and midfoot strike is more frequent among habitual barefoot runners compared to habitually shod runners who mostly rearfoot strike. The benefit of landing on the forefoot before bringing down the heel is smaller collision forces even on hard surfaces which could be involved in protecting the body from impact related injuries (Lieberman et al., 2010). However, habitual conventional, rearfoot striking shoe wearers do not necessarily change to a forefoot or midfoot strike automatically when running barefoot (Hein & Grau, 2014).

For the past decades, therapists and researchers have been working with and researching the effects of barefoot training with regard to ankle stability, strength, balance and injury prevention. Villiers and Venter (2014) studied the effect of gradually increasing a barefoot training program for eight weeks on healthy female competitive netball players. The effect of the barefoot activity showed significant improvements in the athletes' ankle stability, agility and speed, which reasonably improves performance and prevents ankle injuries. It is also suggested that a barefoot training programme can prevent injuries in runners through internal strengthening of the foot, which may increase supportive structures (Hart & Smith, 2008; Robbins & Hanna, 1987). In a recent pilot study, athletes with chronic injuries of the iliotibial band and calcaneal tendon received a barefoot training program consisting of seven exercises: barefoot walking/running, balance task, foot eversion/inversion and flexion/extension during a four week intervention period. Compared to a control group, the intervention group showed reduction of rear-foot impact, improvement in balance through less sway and experienced less pain after the training program (Rowlands & Plumb, 2019).

Balance

Balance is correlated with injuries and falls; however, balance training as a single intervention has had mixed results on the injury rate in athletes (Hrysomallis, 2007). The scientific literature indicates that barefoot training or balance training as a part of a multifaceted intervention is more effective for injury prevention than balance training on its own (de Villiers & Venter, 2014; Rowlands & Plumb, 2019). Zech et al. (2018) show that habitual barefoot children and adolescents have better balance compared to their shod counterparts and emphasizes the importance of barefoot habits for the development of motor skills such as balance for this age group. The balance modulation role in the lower leg muscle gastrocnemius medialis is reduced when walking in conventional shoes (Franklin, Li, & Grey, 2018). The narrow fit also affects walking patterns: every weight-bearing step is prevented because the natural expansion of the foot is reduced which affects balance and increases the risk of falling (Rossi, 1999).

Falls have been identified as a primary cause for injuries in training. In the U.S, between the years of 2011-2014, 8.6 million sports-related injuries were reported each year and 27.9% resulted from falls (Sheu, Chen, & Hedegaard, 2016). Elderly, western wearing shoe people have a foot problem prevalence of 87% and foot problems in itself is a fall risk factor associated with worse balance (Menz & Lord, 2001). Besides toe deformities, toe weakness, stiff ankles and lack of plantar tactile sensitivity increase the risk of falls in older people (Menz, Morris, & Lord, 2005; Mickle, Munro, Lord, Menz, & Steele, 2009). Furthermore, toe weakness contributes to developing hallux valgus and lesser toe deformities. The presence of such deformities increase the risk of falling since the toe flexor strength is crucial in maintaining the balance (Mickle et al., 2009). Despite research on functional adaptations, it remains unclear to what extent balance has been negatively influenced by the wearing of conventional shoes.

The barefoot shoe

With a large amount of evidence supporting the positive effects of barefoot activities, minimalist running shoes were developed and researched as a training device at the beginning of the 21st century. In contrast to conventional shoes, they feature a flexible sole with little cushioning, no arch support, an upper that weighs 200 g or less, a heel-toe differential of no more than 7 mm and a heel stack of 20 mm or less (Davis, 2014; Coetzee, Albertus, Tam, & Tucker, 2018). The aim of the shoes is to mimic the foot's function in a barefoot state, while providing protection from hazards such as punctures of the foot and extremes in surface temperatures (Miller, Whitcome, Lieberman, Norton, & Dyer, 2014; Lieberman et al., 2010). A few years later, out of the same idea, came the barefoot shoe. Similar to the minimalist shoe, the focus of this shoe was to mimic the barefoot state. The difference of this shoe compared to the minimalist and conventional shoes was the very thin sole that had no difference in height between the heel and forefoot (zero drop) and a wider toe box. Those who wear the shoes do not only use them for training but also as everyday shoes. When minimalist running shoes gained traction a new paradigm appeared. However, without a foot strengthening program and a very short transition period from conventional shoes to minimalist shoes, negative effects such as overuse injuries increased substantially (Davis, 2014).

Picture 1. Example of a barefoot shoe.

When habitually rearfoot striking shod people ran barefoot and in minimalist running shoes, they showed similar striking patterns, indicating that the minimalist running shoes do feature the barefoot state in some regards, while the researchers also stating the importance of improving the shoe as to mimic the barefoot state even further (Hein & Grau, 2014). The results reported by Franklin et al. (2018) show similar muscle reduction and activation in the lower leg muscles between walking in minimalist shoes and walking barefoot, though the minimalist shoes represent an intermediate state between being barefoot and using conventional shoes. Running in the barefoot shoe known as Five fingers resembles barefoot running patterns, and with peak pressure being lower as in a barefoot state, compared to conventional shoes (Squadrone & Gallozzi, 2009). Studies on children walking barefoot show an increase in forefoot width and spreading under load (Zech et al., 2018). This was restricted when wearing conventional shoes (Wolf et al., 2008). The wider toe box of the barefoot shoe provides more space for this spread (Xiang, Mei, Fernandez, & Gu, 2018). Tibio-talar range of motion (ROM) was similar in the barefoot state and minimalist shoe state, while differing in the conventional shoe state. The authors call for the use of flexible soles for children as also foot torsion ROM was constricted in the shoe state compared with barefoot (Wolf et al., 2008). Patellofemoral pain syndrome and iliotibial band syndrome are associated with weakness in the hip abductors and the external rotators. These pathologies are not common in either barefoot runners nor minimalist shoe runners but are more present among the conventional shoe running group (Dierks et al., 2008; Lohman, Balan, Sackiriyas, & Swen, 2011).

Ridge et al. (2019) have shown that merely walking in thin soled, zero drop minimalist shoes strengthens the foot muscles similarly to that of a barefoot training program and emphasize that simply changing to this kind of shoe may result in greater compliance. Similarly, the Holowka et al. (2018) study shows that foot strength is related to footwear use**.** Conventionally shod people had weaker intrinsic foot muscles and were predisposed to the development of flat foot compared to people living in barefoot shoe sandals. In contrast, barefoot shoe running has a strengthening effect on the longitudinal arch (Robbins & Hanna, 1987; Miller et al., 2014). When studying the effects of minimalist shoes in high intensity workouts, Goldmann, Potthast and Brüggemann (2013) found that training in minimalist footwear strengthened the toe flexor muscles. Interestingly, Xiang et al. (2018) reported that barefoot shoe running decreased hallux valgus and altered the plantar loading distribution. However, studies on the effects of these shoes have been focused almost exclusively on running or walking, and very little on other aspects, such as balance (Franklin, Heneghan, Bowen, & Li, 2015; Smith et al., 2015). It is unclear if these changes due to habitual barefoot shoe wearing have an effect on balance. The effects of barefoot shoes have not been researched with regard to this, even though balance seems to be an important part in injury prevention in sports as well as falls among the elderly.

Aim

The main aim of this study was to investigate if static stance balance (SSB) is influenced by habitual barefoot shoe wearing. Another aim was to provide research on the Unipedal Stance Test (UPST) in different shoe conditions.

Research question 1: Is there a difference in static stance balance between habitual barefoot shoe wearers and wearers of conventional shoes?
Research question 2: Are the possible outcomes influenced by the type of balance condition measured (shod vs barefoot and eyes open vs eyes closed)?

It was hypothesised that the habitual barefoot shoe wearers have better static stance balance than the wearers of conventional shoes when shod. It was also hypothesised that the habitual barefoot shoe wearers would show better static stance balance than the wearers of conventional western shoes when standing barefoot.

Method

This study design was a case-control cross-sectional study. The control group were healthy physically active people with no experience in wearing barefoot shoes. The case group consisted of people that had used barefoot shoes during their daily activities for at least three years. Control subjects were recruited from local training centers. Recruitment of the case subjects was done within the local barefoot shoe community via social media and personal messages. General exclusion factors included whether the participants were injured in the lower extremities in the last three months. If only one of the subject's legs or feet were compromised at the time of the test they would be asked to pick the healthy leg. Further, exclusions were also made if the participants took medication that could affect balance, suffered from any ailments or were outside the required age group (18-49 years). Group specific exclusion factors for the control subjects included whether barefoot shoes had been worn at any point in their life. Group specific exclusion for the case subjects included whether barefoot shoes had been worn regularly for less than three years. Further exclusion factors for the case subjects were if conventional shoes had been worn regularly during the same time period and if they had worn shoes that were not approved as barefoot shoes. Test specific exclusion criteria were if the test subjects practiced the test during the resting intervals as well as if they did not follow the prescribed instructions during the test (see Figure 1).

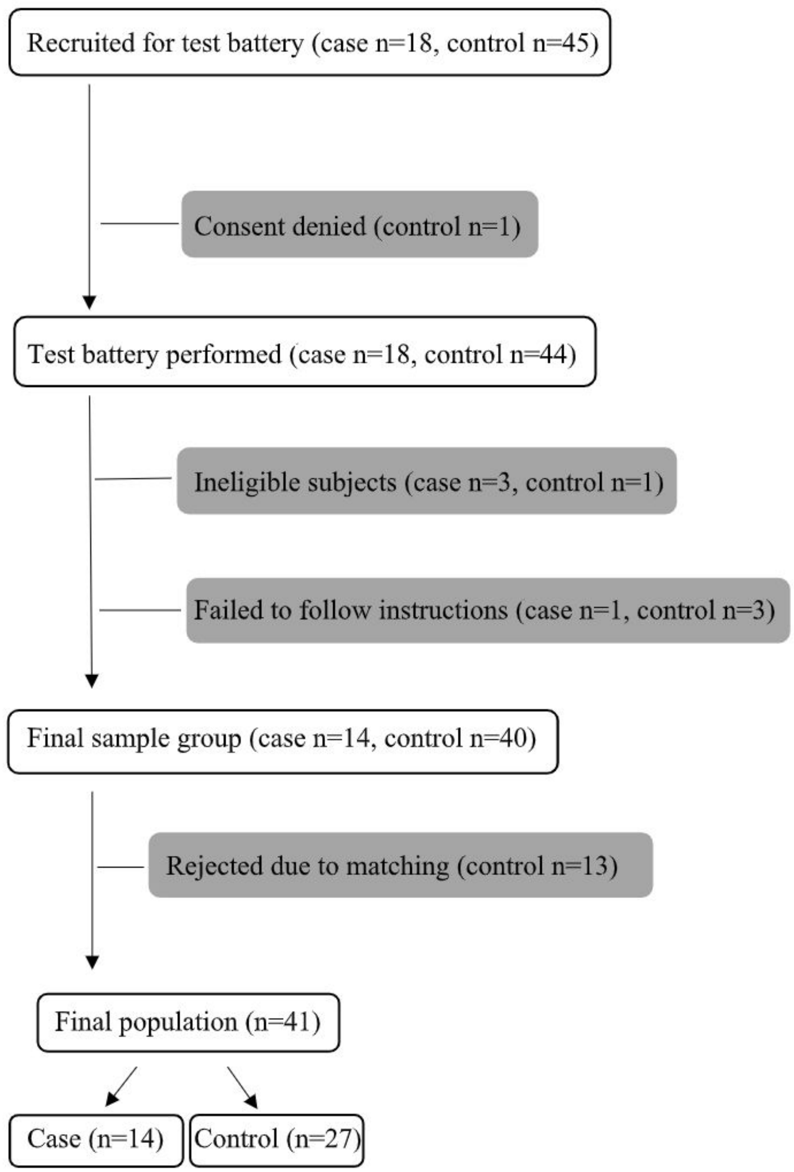

Figure 1. Flow chart of the recruitment, rejection and matching process.

Data collection

The tests were performed at different locations in the southwest of Sweden within a three-week time period. Permission from the necessary authority figures was provided for and an invitation was sent to the control group volunteers via social media. The recruitment of controls was done on-site. Before attempting the test battery, all recruited participants filled in a short survey (see

Attached files 1 & 2) on site containing a set of questions pertaining to the participants eligibility. The survey would be somewhat different depending on what group the participant belonged (see Attached files 1 & 2). After the survey was filled out it was checked by one or more of the test leaders in order to assess whether the necessary requirements were satisfied. The participants were then taken to a privately situated area as could be provided, in order to decrease the likelihood of environmental disturbances and in accordance with social distancing decrees (more on Covid-19 below). The participants were reassured of anonymity and that the data would not be used for anything besides this study, nor could the results be traced back to the participant. This was written in the survey and orally informed. No name or personal number was recorded and all who participated were of legal age. It was clearly communicated to each and every participant that participation was completely voluntary and that no reason needed to be provided if the participant wishes to leave the study at any point. The code of conduct was within the ethical framework of Good Research Practice (2017).

The Swedish public health authority issued recommendations regarding the Covid-19 pandemic (Folkhälsomyndigheten, 2020) which were followed when conducting the tests. Surgical gloves were therefore used by the test leaders, the blindfold was thoroughly sanitised between every participant and open spaces were prioritized. Furthermore, no contact was made with individuals older than 60 years. After the ethical briefing, all who provided consent were admitted to begin balance testing immediately.

Instructions regarding the test battery were carefully conveyed to the participant with words and visual instructions. It was explained that the first test involved balancing with shoes and a blindfold (SB), the second, with shoes without a blindfold (SO) where the participant was asked to focus on a single spot on the wall at eye level. The third, barefoot with a blindfold (BB), and the fourth and last was barefoot without a blindfold (BO), which gave a grand total of four test sets. A rest period of 5 minutes was provided for the subjects in between the first two and last two test sets in order to allow for the dissipation of fatigue, in accordance with the UPST (Springer et al., 2007). At least two test leaders were present during the various data collection events and two researchers wielded the exact same Protouch model stopwatch when timing the subjects for the balance tests. If one researcher made a mistake with their stopwatch there would be a backup, and if both timed the participant well, an average time would then be calculated. The data was recorded in a spreadsheet for each group.

The subjects were allowed a quick trial run before each blind test and that the chosen foot would be the one used for all tests. It was explained and shown how the arms would be placed across the chest and the non supporting leg raised to touch their calf/shank with the knee pointing forwards as shown in Picture 2. It was acceptable to sway back and forth, and from side to side as well as flex the ankle, knee and hip joints. If the foot repositioned (shuffled across the floor) in order to regain balance the test set would be terminated. The set would also be stopped if the knee of the non-standing leg shifted from a forward position to a sideways position or if the arms uncrossed or were raised from the body. The test was automatically terminated if 60 seconds passed and the test was initiated at the moment the participant raised their foot.

Picture 2. Representation of how the UPST was performed (here the BB test).

Questionnaires

The purpose of the survey was to gather data pertaining to the participants' shoe choices, injuries and allowed for later matching. In detail, the cases were asked about their:

- Amount of time spent in barefoot shoes
- Age
- Injury and medication status
- Gender
- Training level
- Level of barefoot shoe habituality
- Brands of barefoot shoes that had been used
- Barefoot activity level

The survey for the control group asked about their:

- Barefoot shoe usage
- Age
- Injury and medication status
- Gender
- Training level
- Barefoot activity level

The balance test

In order to credibly answer the research questions and meet the aim, the UPST was deemed appropriate. Springer et al. (2007) provide normative values for SSB using the Unipedal Stance Test (UPST), which is a functional standardized test that has been conducted on large populations. It can be utilized with very limited resources and requires little training on the part test leaders. The test measures SSB and is used to quantify gait performance and fall status (Springer et al., 2007).

The original test by Springer et al. (2007) had the participants crossing their arms across the chest. Subjects picked a limb and stood barefoot. The other limb was to be raised and placed just next to the supporting limbs ankle. All participants were asked to focus on a spot (at eye level) stuck to the wall for the whole “eyes open test”. The moment the participant raised the non-supporting foot, the measurement phase started. The measurement would be stopped if the participant utilized their arms for balance correction, if the arms were uncrossed, shuffled with the supporting foot on the ground, reached the ceiling value of 45 seconds, touching the stance leg with the raised foot or recovered balance by moving it about.

Slight adaptations of the Springer et al. (2007) UPST were agreed upon in this study. These deviations include:

- Not deducing the dominant foot
- The use of a blindfold instead of closed eyes
- A ceiling value of 60 seconds instead of 45 seconds
- One trial given for each situation, with a trial run before blind, instead of three trials per test.
- Including shod tests instead of only a barefoot test

- The non-standing foot being held against the standing leg instead of at its side

Data analysis

The collected data were analysed using IBM SPSS statistical program (version 26) for Windows. Before data analysis, controls were matched to case subjects by age and PA.

Descriptive statistics (mean, standard deviation (s.d.) and p-value) was used to describe the sample as well as the base values of the balance tests. In order to evaluate group differences for the different tests, the students' independent samples T-test was used. Statistical significance threshold was set at $p<0.05$.

Results

The description of the samples is shown in Table 2. The scores for all the balance tests are shown in Figure 2. After matching the control and case (n=41) for age and PA, the results show a statistically significant difference between the case control groups in the SO ($p<0.01$) and BO ($p<0.05$) balance tests. The case group performed better in the blind tests; however, there were no significant differences between the groups while conducting the tests blind. Furthermore, the tests barefoot and in shoes showed the same scores. A detailed description of all the balance test scores are shown in Table 3.

Table 2. Description of study sample post matching.

	Control group	Barefoot shoe group	p-value
Age	36 ± 10	37 ± 7	0.923
PA level (scale 1-3)	2.2 ± 0.6	2.1 ± 0.9	0.880
BF activity level (scale 0-3)	1.0 ± 1.2	1.8 ± 1.0	0.032

PA level= Level of physical activity; BF activity level= Level of activities done barefoot. Test values are mean values ± standard deviation.

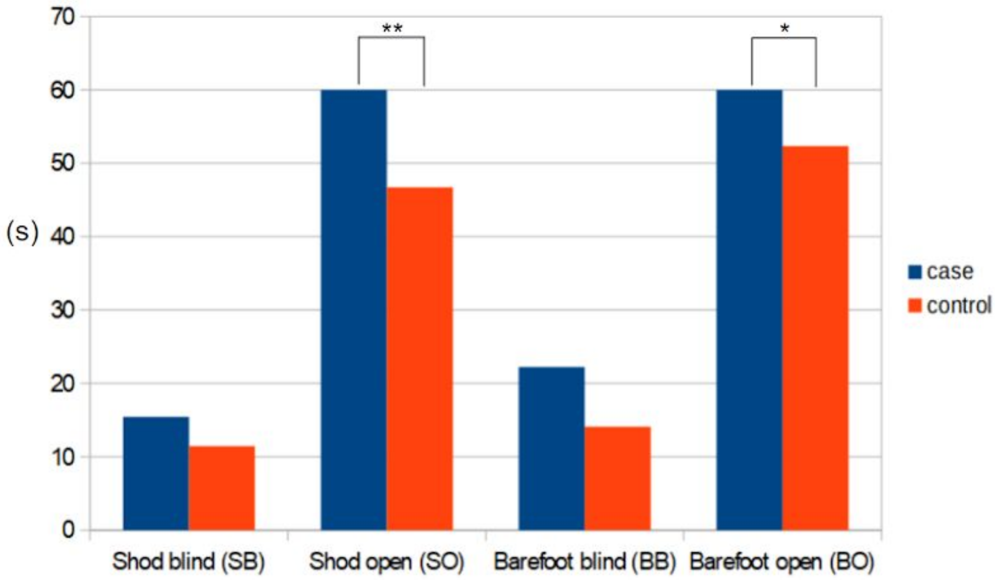

Figure 2. All balance test scores. * significant at p<0.05, ** significant at p<0.01) Total amount n=41.

Table 3. Balance test scores for all tests.

Test (in sec)	Control group	Barefoot shoe group	p-value
SB	11 ± 15	15 ± 17	0.477
SO	46 ± 20	60 ± 0	0.002
BB	14 ± 15	22 ± 20	0.193
BO	52 ± 18	60 ± 0	0.039

SB = shod test blind; SO = shod test eyes open; BB = barefoot test blind; BO = barefoot test eyes open. The test values are mean values ± standard deviation.

Discussion of results

Main findings

The first research question focused on identifying a possible difference in SSB between the barefoot shoe group and the conventional shoe group. The results showed that the barefoot shoe group had better stance balance with shoes on, which partially confirms the first hypothesis. This was statistically significant ($p<0.01$) in the SO, but not in the SB test. The results confirm the second hypothesis to an extent, showing that the two groups also differ in SSB in the BO test. The case group displayed significantly ($p<0.05$) better stance balance in this test than did the control group. Interestingly, all participants in the barefoot shoe group reached the ceiling time of 60 sec in both the shod test and barefoot test with eyes open.

To the authors' knowledge, this is the first study that has been conducted on the balance of habitual barefoot shoe people. As no other studies exist on the topic it is difficult to compare the results. There is; however, some limited research on balance improvement with the use of barefoot shoes. In one case control study of 16 healthy adults, barefoot shoes were worn for 1-2 hours a day for 8 weeks (Dobson, Solecki, Boazzo, & Wiles, 2013). The dynamic balance scores improved an average of 8.78 seconds at the end of the intervention compared to the baseline tests. In between the measurements, the subjects took no other measures to improve their balance other than wearing the barefoot shoes for the short instructed time. In another study, Franklin, Grey and Li (2017) examined the changes to barefoot shoes for a cohort of 13 active, older persons. After the four month intervention, the subjects improved significantly in the functional balance tests at the post measurements. They also experienced improvements in perceived balance and confidence. It is important to note how the group only wore the shoes for a few hours a day and used their conventional shoes the remainder of the time. These results support the findings in our study. It is interesting to note how these changes in balance occured in a shorter amount of time and without the subjects being habitual barefoot shoe wearers.

Franklin et al. (2017) also found significant improvements in toe strength in the post measurements. The authors discuss how toe strength could have a positive effect on balance, which corresponds to previous findings showing that toe flexor strength is crucial in preventing falls (Mickle et al., 2009). These effects could have occured in the barefoot shoe group in our study, which would explain why they showed better balance than the control group. Those who used their great toe more seemed to perform better than those who did not use it as much. This was noticed in both groups. Ridge et al. (2019) have shown that walking in zero drop minimalist shoes strengthens the intrinsic foot muscles similarly to a foot strengthening program. Although Ridge et al. (2019) did not study the groups with regards to balance, it is possible for the stronger intrinsic foot muscles to have an effect on this parameter. The case group in our study could have had similar muscle adaptations, being habitual barefoot shoe wearers of at least three years. Chou et al. (2009) constrained the great toe when testing healthy women in single leg stance. Compared to the unrestricted test, the women performed statistically worse when not being able to use the great toe. Zhang, Schütte and Vanwanseele (2017) studied single-leg balance by measuring sway in relation to the muscle morphology in recreational runners. They found that those with a larger abductor hallucis (a muscle of the great toe) showed a statistically less amount of sway in comparison to those with a smaller muscle. These adaptations could have occured in our barefoot shoe group, explaining the better balance.

In connection to the strength of the great toe, it was noticed in the barefoot tests that those with a straight or varus great toe, seemed to perform better than those who had a more valgus great toe. The wider toe box of the barefoot shoe could make it possible for the great toe to be in a straighter direction, as supported by the fact that the barefoot shoe provides the possibility to minimize hallux valgus (Xiang et al., 2018). This is also supported by the fact that the elderly with more foot deformities, such as hallux valgus, are at a higher risk for falls (Menz & Lord, 2001; Mickle et al., 2009). In the control group in our study, the younger subjects were generally the ones with a straighter great toe. Studies on foot deformities show how the adaptations to the foot increase with age, with the foot having adapted to the form of the wedged toe box with the longer use.

The difference in the eyes open tests could be influenced by the fact that barefoot shoe people have lower peak plantar pressure, similar to barefoot people, and therefore distribute the force on a wider base (D'AoÛt et al., 2009). The results in the SO tests could be partially due to the fact that the barefoot shoe provides more space for this forefoot spread under load (Wolf et al., 2008). It is of immense importance for shoe companies, including barefoot shoe companies, to respect the shape of the natural bare foot when developing shoes. This is especially important when designing shoes for generations to come, as many foot deformities could be avoided by respecting the morphology and expansion of the growing foot (Frey et al., 1993; D'AoÛt et al., 2009).

Research question two regarded whether the outcomes were influenced by the type of balance condition measured. The results show that the barefoot shoe group performed better in the eyes close tests. However, these differences between the groups were not significant. Due to the high s.d. and lack of significance, the null hypothesis still stands. This indicates that the barefoot shoe is only beneficial for SSB while the optic nervous system can be used. The tests barefoot and in shoes showed the same scores, indicating that barefoot shoe wearers are not influenced by the difference of wearing shoes or being barefoot in regards to SSB. Nevertheless, this could also simply be due to the ceiling value not being set high enough. Possible reasons for the lack of significance and high s.d. for these specific tests are discussed in the discussion of method.

Difference in sway

It was noticed by the test leaders how the case group seemed to show a lower degree of sway than the control group. Proceeding the research within SSB could preferably focus on using pressure plates, which is a common measuring tool with high reliability when measuring sway (Goble & Baweja, 2018). The significantly higher time in the BO and SO tests could be because the barefoot shoe is similar to the barefoot state with regard to sway. In a barefoot state, there is generally more sway for conventionally shod persons. Similarly, the amount of sway is higher for those not accustomed to the barefoot shoe (Smith et al., 2015). In a recent study on the dynamic balance of young adults, the barefoot shoe state proved to be similar to the barefoot state (Smith et al., 2020). This could mean that balance, being a highly adaptable skill (Zech et al., 2018), is given the possibility of improving more in the barefoot shoe state. This would result in better balance for the barefoot shoe group in both the barefoot shoe state as well as the barefoot state, as demonstrated by the results of this study.

Discussion of method

Conduction of the test

After completion of the data collection and analysis, one particular change from Springer et al. (2007) stood out as less than optimal. The participants were not given additional attempts at the SB and the BB tests. Springer et al. (2007) did allow for three attempts for both the blind and eyes open tests. This study deviated from Springer et al. (2007) by the fact that balance tests were performed in the shod state as well as barefoot which gave four base tests. If additional attempts were allowed for the blind events, it was feared that it would take up too much time, preventing additional individuals from participating and also tiering the test subjects, hence risking bias. Not adding attempts were not an issue with the eyes open tests, as those were easier to perform. Nevertheless, it did prove to be an issue in the eyes closed test, as shown with the great s.d. of the SB and BB tests presented in Figure 2. Unfortunately, many of the participants failed the eyes closed tests due to the fact that it was unfamiliar and initially difficult when removing the optical sensory system. This is supported by the fact that the groups performed better in the latter blindfolded test, compared to the former.

When changing some parts of the conduct, two deviations seemed to ensure a higher reliability for the study. The first being the use of a blindfold. This ensured the blind state for the participant, while also aiding the test leaders to focus on other possible deviations. As a result, this aided in consistency. The other was having the participants puting the side of the foot on the shank of the balancing leg instead of having it by the side not touching. Any loss of contact would terminate the test, instead of there being a difficult-to-agree-upon angle of deviation that would stop the test. Springer et al. (2007) changed the ceiling value from 30 seconds to 45 seconds as the limit of testing time, as many reached the 30 second ceiling value in a previous investigation. In this study, that cognition was adopted and extended to 60 seconds. This because the case group was believed to possess greater balance, and so would provide less bias if fewer reached the ceiling. The results would offer stronger data for analysis.

Experience of participants

As is the risk in many studies, those in the case group accepting the invitation may have perceived their abilities to be of a high standard, while those refusing believing their balance to be poor. This would cause an overrepresentation of above average subjects in the case group. This effect may have been mitigated by the fact that several controls refused to participate, believing their balance to be poor. As the controls explicitly expressed this while the cases did not, it may be possible for only the control group to have consisted of participants with better-than-average balance abilities. It was observed that a number of cases showed signs of nervousness during the tests. The very fact that the cases knew of their status as “cases”, as well as knowing about the test several days beforehand, might have influenced their test scores. In contrast, the performance pressure may largely have been absent for the controls where the tests were performed shortly after recruitment and the pressure to perform may therefore have been absent.

Data collection error

A mistake regarding data collection was noticed post analysis. One subject was preliminarily placed in the case group, who had for many years used barefoot shoes for training purposes, but conventional shoes in everyday life, thus ineligible to both groups. The paperwork pertaining to this individual was due to be highlighted. Despite this, the categorization process made an error and the subject was included in the analysis. The consequence of this may have influenced the results of this study.

Physical activity level

It is possible that those included in the study were more physically active than the general population. The barefoot shoe wearers could be more interested in health and movement and the control group was recruited at different training facilities. The sample was too small to only compare those with a low PA level. This could be supported by the high average time on the conventional shoe wearers BO test (53.31 sec) which exceeds the normative value provided by Springer et al. (2007). This comparison should however be made cautiously as the ceiling of the normative values was set at 45 seconds. It is therefore entirely plausible that our findings only apply to more active persons.

Barefoot shoe characteristics

Even though the shoes worn by the barefoot shoe group were wider than conventional shoes, most of them did not respect the form of the natural bare foot. This is especially true at the hallux part of the shoe, where the great toe would be unable to follow the direction of the metatarsal bones (Hoffman, 1905). Since Xiang et al. (2018) show that it is possible for barefoot shoe activities to reform the morphology of hallux valgus, it is arguably possible for the foot to retain its natural shape if the shoe allows it to. In Picture 1 there is space for this angle for the hallux. However, in most barefoot and minimalist shoes, the hallux part of the shoe is pushed in towards a valgus direction. An overwhelming majority of the observed barefoot shoe cases had a hallux that was not straight, with this possibly playing a main role in balance control.

Shoe definitions

It is difficult to distinguish between the definitions of the barefoot shoe and minimalist shoes in the scientific literature. Since minimalist shoes being the overall definition, as described by Davis (2014), a barefoot shoe is technically a minimalist shoe. Nevertheless, a minimalist shoe is not a barefoot shoe if conditions, as previously defined, are met for this type of shoe. This can be confusing for readers and researchers alike. To date, the barefoot shoe goes under the umbrella term minimalist shoes, even though it shows differences in characteristics. Some studies have also categorized the different shoes quite carelessly. A clear and unified definition of the barefoot shoe and its features (such as toe box width and zero drop) is key since this assures consistency in the scientific literature, as well as clinical applications. Another name that is used for the barefoot shoe is “true minimalist” shoe, which is also a possible definition. It is not, however, unanimously agreed upon what constitutes a true minimalist shoe in the scientific community and constitutes a key reason why the term “barefoot shoe” was used for this paper.

Strengths

The fact that much of the investigation was taken to the participants probably allowed a larger number to participate in the study contributing to greater statistical stability. The surveys were filled out on site allowing for any uncertainty to be explained directly in a face-to-face manner. This may yield more accurate survey answers and contribute to a stronger study design. The statistics gathered during the data collection constituted such robustness that a student t-test was possible. Springer et al. (2007) only provide values for the barefoot state. This research adds both values for conventional shoes as well as barefoot shoes to begin to understand the relationship between different shoes and SSB. It adds research on what shoe type is advantageous for balance for both the shod condition as well as the barefoot state.

Limitations

This study consists of several limitations. The first being, as mentioned, the fact that there was no possibility of matching the controls and cases with the aspect of barefoot training due to the small sample size. The case group trained significantly more barefoot than did the control ($p<0.05$). This could be a possible confounding factor in all test scores, since barefoot activities are shown to improve balance (de Villiers & Venter, 2014; Rowlands & Plumb, 2019). The significance in the eyes open tests should be interpreted cautiously because of this limitation.

Another possible limitation not accounted for in this study was how much and what kind of balance training had been done. This was excluded as those variables proved to be too numerous and complex, and could not be encompassed thoroughly with the time limitation and smaller sample size of this study.

Other limitations include the human factor when using stopwatches. A more objective measuring tool would be to measure sway using force plates. It was reasoned that such an approach to measurements would draw too small of a sample size, since participants would be needed to come to the Centre for Health and Performance at the University of Gothenburg in order to perform the tests. It is possible that this would dissuade potential participants, especially in the control group, and thus, was not chosen. There were many small differences in how the test was performed. Even if several of those were excluded due to incorrect performance, this tool is not as objective as using force plates and measuring sway.

Conclusions

This study compared the difference in SSB between habitually barefoot shoe wearers and conventional shoe wearers. The barefoot shoe wearers showed statistically better balance in both eyes open tests. These preliminary findings suggest that when acclimated to the barefoot shoe, it provides a better situation for SSB compared to conventional shoes. It could indicate that balance improves from wearing barefoot shoes. However, it is important to investigate if barefoot shoes indeed improve balance with prospective studies. To date, the evidence is low regarding improved balance from using barefoot shoes. Future studies on the topic are of great importance since balance is correlated with injuries and falls. This study did not include children or older individuals which are also important groups to study regarding balance and barefoot shoes. Important aspects include barefoot shoes and the growing foot, as well as barefoot shoes and the minimization of foot deformities, as these deformities increase the risk of falls among older adults.

Implications for health promotion

Thin soled, flexible shoes that respect the natural form of the foot are important to promote from the perspectives of foot deformity, injury prevention, and possibly that of balance ability. With barefoot shoe wearers showing better balance, it could be possible for activities in barefoot shoes to improve balance and thus minimizing injuries. By decreasing injuries and improving performance, this could have implications for the health and sport sciences as well as being important for professionals working within these fields. This could potentially also be an important part in rehabilitation, reducing falls for the elderly and improving quality of life as well as minimizing costs for the health care system.

Conflicts of interest

We wish to confirm that there are no known conflicts of interest.

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Attached files

Survey barefoot shoe group (Swedish)

ENKÄT - Balanstest

Barfotaskogrupp

Den här enkäten är del av en studie från Göteborgs Universitet där vi vill mäta balansen på personer mellan 18 och 49 år i förhållande till deras skoval. Enkäten tar ett par minuter att fylla i. Det är helt fritt att delta och om du börjar behöver du inte fullfölja studien eller enkäten om du inte vill. Du får lämna utan att ge oss forskare en anledning. Du väljer att delta i studien genom att fylla i den här enkäten. Alla svar från enkäten och svaret från testerna kommer hanteras anonymt och endast användas till denna studie. Tänk noga ut dina svar. Fråga testledarna om du har någon fundering.

1. Har du använt barfotaskor i minst tre år?

   Markera endast en oval.

   ◯ Ja - Om Ja gå vidare till nästa fråga.

   ◯ Nej - Om Nej tack för din medverkan!

2. Ålder (yngre än 18 eller äldre än 49 så tackar vi för din medverkan!)

   ____

3. Är du eller har du varit skadad under de tre senaste månaderna? Alternativt har du någon åkomma, medicinering eller liknande som skulle kunna påverka din balans?

   Markera endast en oval.

   ◯ Ja (om "ja", kontakta testledarna)

   ◯ Nej

4. Om du svarat Ja på föregående fråga, Vilken skada/åkomma/medicinering är det du har eller har haft?

Allmän information

5. Kön

Markera endast en oval.

- ◯ Kvinna
- ◯ Man
- ◯ Annat

6. Hur många dagar i veckan brukar du träna?

Definition av träning - Fysisk aktivitet av pulshöjande eller muskelstärkande kroppsrörelse med ökad andning.

Markera endast en oval.

- ◯ 0
- ◯ 1-2
- ◯ 3-4
- ◯ 5-6
- ◯ 7+

Ämnesspecifika frågor

7. Hur ofta har du barfotaskor på dig? Välj det alternativ som passar bäst in på dig.

Markera endast en oval.

- Hela tiden, om jag inte är barfota
- Alltid, förutom speciella situationer såsom bröllop, begravning mm.
- Använder till vardags men inte till träning / jobb
- Använder till träning / jobb men inte till vardags
- Någon gång i veckan
- Övrigt: ______________________

8. Vilka märken av barfotaskor har du använt de senaste tre åren?

____

9. Tränar du eller utför aktiviteter barfota?

Tex Kampsport / Yoga / Gym / Beach volleyboll / Dans / Vandring/ Promenad

Markera endast en oval.

- Ja
- Nej

10. Om du svarat Ja på föregående fråga, vilken aktivitet och hur ofta?

____

____

____

____

Tack för din medverkan!

Anton Lossev, Anna-Karin Byström, Adam Thornberg
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Hälsopromotion Idrottsvetenskap
Handledare: Prof. Stefan Grau, stefan.grau@gu.se
Göteborgs Universitet

Survey control group (Swedish)

ENKÄT - Balanstest

Kontrollgrupp

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1. Använder du eller har du använt barfotaskor?

   Markera endast en oval.

   ◯ Ja - Om Ja, tack för din medverkan!

   ◯ Nej - Om Nej, gå vidare till nästa fråga.

2. Ålder (om yngre än 18 eller äldre än 49 så tackar vi för din medverkan)

   ____

3. Är du eller har du varit skadad under de tre senaste månaderna? Alternativt, har du någon åkomma, medicinering eller liknande som skulle kunna påverka din balans?

   Markera endast en oval.

   ◯ Ja (om "ja" kontakta testledarna)

   ◯ Nej

4. Om du svarat Ja på föregående fråga, Vilken skada/åkomma/medicinering är det du har eller har haft?

____

____

____

____

____

Allmän information

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- Kvinna
- Man
- Annat

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Markera endast en oval.

- 0
- 1-2
- 3-4
- 5-6
- 7+

Ämnesspecifika frågor

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Tex Kampsport / Yoga / Gym / Beach volleyboll / Dans/ Vandring/ Promenad

Markera endast en oval.

- Ja
- Nej

8. Om du svarat Ja på föregående fråga, Vilken aktivitet och hur ofta?

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