Title: How does orthotic walker boot design influence lower limb and trunk function during gait?

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Brief Title: Does orthotic walker boot design influence biomechanics during gait?

Abstract

Background: Undesirable lower limb gait deviations have previously been reported when wearing orthotic walker boots, therefore there is a need to optimise orthotic walker boot designs to facilitate normal gait. **Objective:** This study explored the biomechanical effects of two designs of orthotic walker boot on the lower limb and trunk compared to usual footwear. **Study Design**: A repeated measures analysis of variance (ANOVA) was used to evaluate selected kinematic and kinetic variables under different walking conditions. **Methods**: Sixteen healthy participants walked in three conditions using: *Walker A* (Airselect Elite, Enovis, USA), *Walker B* (Townsend XLR8 Series Walker, Thuasne, France) and a usual *shoe*. A 10 camera motion analysis system and 4 force plates were used to collect kinematic and kinetic data. **Results:** Gait speed was significantly slower in both orthotic walker boots, and significantly decreased ankle range of motion (ROM) which is their primary function. Significant deviations in normal knee and hip kinematics and kinetics, shank to vertical angle and pelvic and trunk movements were noted with both walker boots, with the greatest deviations from the shoe condition observed in Walker B. Recline and incline shank angular velocities showed the greatest differences in Walker B which could be associated with adverse knee joint moments and a significantly greater perceived ease of walking in Walker A. **Conclusions:** Orthotic walker boot design significantly affects walking mechanics. Orthotic walkers with greater forefoot rocker profiles and inclined vertical shank angles may at least in part mitigate known gait deviations when wearing orthotic walkers.

Keywords: Gait, Lower limb Orthoses, Joint Mechanics, Rehabilitation, Rocker Sole Profile, Shank to Vertical Angle (SVA).

Background & Aims

Orthotic walker boots are included in clinical practice during the management of foot/ankle fractures [1], severe ankle sprains [1], chronic tendinopathy, [2] post-surgical stabilization [1,2], and in the prevention/treatment of ulceration in individuals with diabetes. [3,4] The advantages of using an orthotic walker boot are multifaceted. [1,2,4] They allow early weight bearing whilst still providing protection, provide effective oedema management, and reduce the biomechanical adverse effects on gait patterns compared to a synthetic walking cast, whilst also allowing removal for rehabilitation, examination and cleaning. [1,2,4] Improved clinical outcomes have been reported with orthotic walker boots, with early mobilization leading to improved ankle joint function, bone strength and faster bone healing. [1] Shorter hospital stays and fewer rehabilitation sessions have also been associated with the cost-effectiveness of using orthotic walker boots over traditional casting methods. [1,2,5]

Orthotic walker boot treatment times can vary from between one and three months, depending upon injury severity or the clinical needs of the patient. [6] Throughout this time, the individual may adopt an altered gait pattern, with undesirable changes to lower limb kinematics and kinetics, which over time, may result in the development of secondary pain. [6] Biomechanical investigations into the effects of orthotic walkers during walking have identified significant, unfavourable effects on knee and hip joint angles and moments. [2,4] Different shank to vertical angles (SVA) or tibial inclination angles [7] and heel, midfoot and forefoot rocker profiles have all been suggested to influence gait patterns to varying extents in different patient groups. [8]

Millions of orthotic walkers are sold globally each year, and although the clinical outcomes are well documented [9–11], limited evidence exists on the effect of these devices on lower limb and trunk kinematics. To improve the biomechanics and ease of walking, changes in the design of orthotic walkers have recently been observed, with greater consideration given to SVAs and rocker profiles. [4] However, to the authors' knowledge, no studies have explored the effects that specific SVA and rocker profile design changes may have on lower limb joint biomechanics to determine how to optimise gait whilst still eliciting the positive clinical outcomes already associated with these devices'. This study aimed to explore the biomechanical and subjective effects of a new design of orthotic walker boot compared to a walker with an existing design, to explore whether design changes have gone some way to normalising gait patterns.

Methods

Design

A within subjects, repeated measures design was used to analyse changes in gait parameters under three conditions.

Participants

Healthy participants without current musculoskeletal injuries or disorders, a history of surgery or traumatic injury to the lower extremities or lower back, and no history of medical conditions that limit physical activity were recruited from university populations. Previous knee extension moment [4] was used to determine sample size and a minimum of ten participants was required. Data collection conformed to the Declaration of Helsinki [12] and volunteers provided written informed consent prior to participation. The study was approved by the University's Health Ethics Review Panel (reference HEALTH 0258).

Procedure

Passive retro-reflective markers were placed on the lower limbs and pelvis using the calibrated anatomical system technique, and segmental kinematics were tracked in 6 degrees of freedom. [13] Markers were placed on the acromions, anterior and posterior superior iliac spines, greater trochanters, medial and lateral femoral epicondyles, medial and lateral malleoli, the head of the 1st and 5th metatarsals, the dorsum of the foot and the calcaneus, and the equivalent placement over these landmarks on the orthotic walkers. Clusters of four non-collinear markers were attached to the body segments of the shank and thigh and on the anterior plate of the walker. [4] Kinematic data were collected at 100Hz using a 10-camera infrared Oqus motion analysis system (Qualisys Medical AB, Sweden), and kinetic data were collected at 200Hz using four AMTI force plates (Boston, MA, USA).

All participants walked along a 10m walkway under three conditions: participant's own footwear (*shoe*); *Walker A* (Airselect Elite, Enovis, USA) and *Walker B* (Townsend XLR8 Series Walker, Thuasne, France), with the orthotic walkers worn on the right leg and the participant's own shoe on the left (Figure 1). Walker A was included as the significant design changes to the rocker profile and SVA angle warrant comparison against current practice, and Walker B was selected as the comparator, due to its widespread use across multiple healthcare systems. Walker A is characterised by a forefoot rocker profile of twelve degrees and a vertical shank angle of four degree (inclined). Walker B is characterised by a shallower forefoot angle (6 degrees) and a vertical shank angle of zero degrees (vertically upright). Boot conditions were worn in randomised order (http://www.randomization.com). Both orthotic walkers were applied as per manufacturer's guidance, including air cell inflation Five repetitions where the participant's right foot landed within the perimeter of a force plate were recorded per condition. Upon completion of the walking tasks, participants rated their perceived ease of walking in both orthotic walker boot conditions on a numerical scale of 0 'very difficult' to 10 'very easy'.

Data Processing and Analysis

Anatomical frames were defined by landmarks positioned at the medial and lateral borders of the joint, from these right-handed segment co-ordinate systems were defined. The kinematics were calculated based on the Cardan sequence of XYZ equivalent to the joint coordinate system. [14] Raw kinematic and kinetic data were exported to Visual3D (C-Motion Inc, USA) and filtered using fourth order Butterworth filters with cut-off frequencies of 6 and 25Hz respectively. Gait speed was calculated from the time and distance between consecutive right heel strikes with the first heel strike being on a force platform. Ankle, knee, hip, pelvis and trunk (defined as left and right acromions and posterior superior iliac spines) angles and external moments were exported and the maximum, minimum and range of motion (ROM) at key events (heel strike, stance phase, swing phase, full gait cycle) were found. Given the specific design differences in Walker Boots relating to the vertical angle, SVA was included. It was calculated as the angle of the right shank relative to the laboratory coordinate system and the minimum (maximum tibial recline angle), maximum (maximum tibial incline angle) and SVA ROM were all reported. [7] Shank angular velocity was calculated as a first derivative of the tibial angle during the stance phase of the gait cycle.

The data distribution for each variable was tested using Kolmogorov-Smirnov tests. For normally distributed data Repeated Measures Analysis of Variance (ANOVA) tests were performed using SPSS v28 (IBM, NY, USA), and mean, standard deviations, main effects and effect sizes were reported (Table 1 and 2). Where a main effect was seen Least Significant Difference post-hoc pairwise comparisons were performed (Table 3). Where the data were not normally distributed Friedman and Wilcoxon signed rank tests were performed. The level of significance was set at $p<0.05$ throughout.

Results

Sixteen healthy participants (10 males, 6 females), with a mean age 30 ± 5.7 years, height 1.73 ± 0.1m and mass 79.7 ± 15.5kg were included.

Gait parameters

A significant main effect was seen for gait speed ($p<0.001$, range 1.23–1.37 m/s). Post-hoc comparisons demonstrated that gait speed was significantly reduced in Walker A ($p<0.001$) and Walker B ($p<0.001$) compared to the shoe, but there was no significant difference between walkers ($p=0.267$).

Kinematics

At the ankle significant main effects were seen during stance and swing phase ($p<0.001$). Post-hoc comparisons showed that both orthotic walker boots performed comparably with no significant differences, however notable differences were seen between the Walkers and the shoe ($p<0.001$). Both Walker A and B significantly decreased ankle plantarflexion angle during stance ($p<0.001$) and swing phase ($p<0.001$) and significantly increased dorsiflexion angle during mid-stance ($p<0.001$).

At the knee significant main effects were seen at heel strike ($p<0.001$) and during swing phase ($p=0.008$), for knee valgus angle ($p<0.001$), and transverse plane ROM ($p=0.038$). Post-hoc comparisons showed that both Walker A and B significantly increased knee flexion angle at heel strike and during stance phase compared to the shoe ($p<0.031$). Walker B had a significantly greater effect on knee flexion angle at heel strike and during stance phase compared to Walker A ($p<0.033$). During the swing phase, significant differences were seen in knee flexion angle, with Walker A reducing knee flexion compared to the shoe and Walker B ($p<0.014$). Walker B had no effect on knee flexion during the swing phase compared to the shoe ($p=0.246$). Both Walker A and B significantly reduced knee valgum compared to the shoe condition ($p=0.003$).

At the hip significant main effects were seen during the gait cycle ($p<0.041$). Post-hoc comparisons showed that both Walker A and B significantly reduced hip adduction angle, internal rotation and coronal plane ROM compared to the shoe ($p<0.005$). Walker B significantly increased sagittal plane ROM compared to the shoe ($p=0.003$).

Both Walker A and B significantly reduced coronal plane pelvic ROM compared to the shoe (p<0.009). Walker A also significantly reduced pelvic obliquity compared to the shoe (p<0.014). Walker A and B significantly increased trunk sagittal plane ROM compared to the shoe (p<0.006).

For the SVA, significant main effects were seen for maximum tibial recline angle (p<0.001), tibial inclination angle (p<0.001) and SVA range (p<0.001). Post-hoc comparisons showed that during early stance phase, the maximum tibial recline angle was significantly different between all conditions, with Walker A and B demonstrating significantly lower recline angles than the shoe (p=0.014, p=0.001) respectively, with Walker B having a significantly lower recline angle than Walker A (p=0.012). Both Walker A and B significantly reduced the maximum tibial inclination angle during late stance phase compared to the shoe (p=0.001, p=0.026) respectively, with no differences seen between Walkers. Similarly, for SVA ROM during stance phase, both Walker A and B showed significantly lower ROM compared to the shoe (p=0.001, p<0.001) respectively, with no differences seen between Walkers. For shank angular velocity, significant main effects were seen during early (p=0.010) and late (p<0.001) stance phase. During early stance phase post-hoc comparisons showed that the angular velocity was significantly greater in Walker B compared to Walker A (p=0.015) and the shoe (p<0.001), with no differences seen between Walker A and the shoe. During late stance phase, similar differences were noted, with Walker B demonstrating significantly greater peak angular velocities compared to Walker A ($p=0.003$) and the shoe ($p<0.001$), again with no differences seen between Walker A and shoe.

Joint Moments

Significant differences in knee extension moments after heel strike were seen between the shoe and the Walkers, with both Walkers demonstrating significantly reduced knee extension moments at heel strike ($p<0.005$). Walker A also demonstrated a significantly reduced knee extension moment compared to Walker B at heel strike ($p=0.050$). Significant main effects were noted in the peak flexion moments during mid stance phase ($p=0.004$). The knee flexion moment during mid stance was significantly greater with Walker B compared to the shoe ($p=0.010$), and Walker A ($p=0.006$), with no differences seen between the shoe and Walker A ($p=0.240$).

During late stance phase significant main effects were seen ($p<0.001$) in peak extension moments. Walker B had a significantly greater peak extension moment compared to the shoe ($p=0.001$) and Walker A ($p=0.019$), with a trend towards a significant difference between the shoe and Walker A ($p=0.053$). Significant main effects were also noted in peak adduction moments ($p<0.001$), with significant reductions observed in Walker B compared to the shoe ($p=0.009$) and Walker A ($p=0.015$).

Significant differences were seen in hip peak adduction moments and rotation moments (p<0.022) between Walker B and the shoe (p=0.009) with Walker B showing greater moments, whereas no significant differences were seen between the shoe and Walker A (p=0.141).

Perceptions

Participants perceived that Walker A was significantly easier to walk in compared to Walker B (p=0.044), with median scores of 6.5 (range 4.0 – 10.0) and 6.0 (range 4.0-8.0) out of ten, respectively.

Discussion

This study aimed to explore how different designs of orthotic walker boots affect gait in healthy participants. The need for further research to identify how to optimise gait whilst wearing orthotic walker boots has been highlighted. [6,15] Previous work has identified that SVAs [7] and rocker profiles can significantly influence gait patterns to different extents. [4] Specifically relevant to the rocker profiles, the apex position and angle, and rocker radius can influence the plantar pressure redistribution and lower limb kinetics and kinematics whilst walking when wearing rocker profile shoes, [16] with smaller rocker radii reducing dorsiflexion and plantarflexion moments at the ankle [17], which have been considered in the design of orthotic footwear. It is also important to consider these factors in the design of an orthotic walker.

In this study, both orthotic walker boots significantly reduced gait speed compared to the shoe, and displayed comparable effects at the ankle, intentionally blocking sagittal plane movement compared to normal walking. Given that an orthotic walker boot's primary function of is relieve and protect affected tissues by limiting ROM at the ankle joint, [18] both walker boots were shown to perform this function to a similar effect, suggesting that the design differences between walker boots does not influence primary function. Biomechanical assessment of remaining lower limb joints may assist in determining whether the different designs of walker boots alter walking patterns to different extents.

At the knee, deviations in normal movement were seen during the loading phase, with increased knee flexion when wearing both orthotic walker boots. Similar findings have been noted previously [2,4,19] and could be associated with the compensation needed due to restricted ankle movement. Results from this study indicate deviations in normal knee movement when wearing both orthotic walker boots, with the greatest deviations observed in Walker B. Walker B, which incorporated a shallower forefoot rocker profile angle, had a significantly greater effect on knee flexion during the loading phase compared to Walker A. During swing phase Walker A also showed less knee flexion compared to Walker B and the shoe possibly indicating that less knee flexion was required to ensure toe clearance. The aim of a forefoot rocker is to enable "rocking" from heel-strike to toe-off, facilitating a more 'normal' gait [19,20]. This study's results indicate that the specific design of the forefoot rocker profile may affect the extent deviation from normal walking, with a shallower rocker profile affecting an individual's ability to 'rock' more than a forefoot rocker profile with a greater angle. A forefoot rocker profile is proposed to aid forward progression of the tibia and facilitate tibial shank advancement when sagittal plane ankle movement is restricted. [8] This study's findings suggest a greater forefoot rocker profile angle limits deviations from normal gait kinematics. Much less work has considered the effect of heel rockers on gait kinematics, [21] although the consensus is that the heel rocker predominantly affects the ankle joint and has a lesser affect proximally. [21–23]

Orthotic walker boots have been shown to affect joint loading at the knee, with greater knee extensor moments observed in the late stance phase in walker conditions compared to a no walker condition. [2,4] In the current study significant decreases in knee extension moments after heel strike were observed in both walker boots, suggesting reduced loading through the knee initially. These reduced extension moments may be associated with reduced loads and may be attributed to the differences in the rocker profiles and SVA between conditions. During the loading phase however, Walker B significantly increased the knee flexion moment (mid-stance phase) and knee extension moment (late-stance phase) compared to Walker A and the shoe, indicating greater deviation from normal walking.

This study also considered the peak SVA which showed that both Walkers had a lower SVA during early and late stance phase, with Walker B showing the greatest deviation. During the stance phase of a normal gait cycle, the shank transitions from a reclined position in early stance phase to an inclined position at late stance phase. [7] Considering the differences between Walkers, Walker B has both a shallower forefoot rocker profile, and a more upright SVA, and these design specifications may prohibit normal shank movement throughout the stance phase compared to the greater forefoot rocker profile and inclined vertical angle of Walker A.

This study also considered the use of shank angular velocity to understand movement control from the reclined position to the inclined position. Although both Walkers had similar differences in the SVA ranges of motion compared to the shoe, the shank angular velocity indicated that Walker A showed a greater similarity to the shoe, with no significant differences in the recline and incline shank peak velocity. When considering the significantly greater knee extension moments observed during late stance phase in Walker B only, the differences in the control of the forward progression of the shank could be responsible for these differences. This would suggest that the increased loading at the knee into hyperextension is associated with the increase in the speed of shank progression seen in Walker B. As these differences were not observed in Walker A, this indicates that significant gait deviations may be mitigated with careful consideration of the SVA and rocker profiles within orthotic walker boot design.

Adaptations at the hip were required to afford walking in both orthotic walker boots, with the most significant findings observed in the coronal and transverse planes. Regardless of walker boot condition, there was significantly less coronal plane hip movement, and a more externally rotated hip was observed compared to normal walking, with Walker B showing greatest deviation. Similar findings have been reported previously, with orthotic walker boots reducing hip abduction ROM compared to a shoe condition.[2] Significant differences were also identified between standardised footwear and orthotic walkers in the transverse plane during stance phase. [4] Walker B also significantly increased the hip ROM in the sagittal plane compared to the shoe, and increased the peak adduction joint moments compared to the shoe and Walker A, overall demonstrating that greater gait adaptations and potentially greater work done by the muscles were required with Walker B. The pelvis and trunk data findings suggest that whilst the walker boots had an effect on pelvic and trunk mechanics during walking, the design differences between boots did not elicit any significant differences.

When considering the ease of walking, Walker A was shown to be significantly easier to walk in compared to Walker B, indicating that the biomechanical differences measured between the two walkers may be associated with a statistically important difference in user experience, however the difference in user experience observed in this study did not reach the threshold for a minimal clinical important change.

Although pertinent findings are presented within this study, it is not without its limitations. This research may be considered more valuable had the participant sample included patients with a relevant pathology. However, it is important to understand the effects of an intervention amongst a healthy population prior to investigation amongst a pathological group. Both of the walker boots included in this study had air cells to assist immobilisation of the foot and ankle and prevent tibial movement within the boot. Considering participant burden and acceptable data collection session times, the pressure of these air cells was not objectively measured or controlled in this study, although they were inflated in accordance with manufacturers' guidance. To strengthen any future studies, recording pressure values within the walker boot to standardise the pressure applied across participants may be beneficial. Another similar limitation is that the plantar pressures were not measured during this study, and therefore the effect of the design changes and materials of the insole and sole of the walker boots remains unknown. Future studies could incorporate plantar pressure to consider this effect.

Conclusion

The results of this study suggest that Walker B required greater gait adaptations compared to Walker A. As hypothesised, specific designs of walker boot have a significant effect on walking mechanics and may have detrimental effects when worn for a period of time. The findings from this study suggest that significant gait deviations may at least in part be mitigated with careful consideration of the SVA and rocker profiles within an orthotic walker boot design with a greater forefoot rocker profile and an inclined SVA facilitating more 'normal' walking patterns.

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Figure Captions

Figure 1: A - Aircast® Airselect Elite (Walker A) with a vertical inclination angle of 4° and forefoot rocker profile 12°, and B - XLR8 Series Walker (Walker B) with a tibial inclination angle of 0° (vertically upright) and forefoot rocker profile 6°

Table Captions

Table 1: Mean (SD), main effects and effect sizes for kinematic variables. Significance level $p<0.05$. * denotes significance.

Table 2: Mean (SD), main effects and effect sizes for kinetic variables (Nm/kg). Significance level $p<0.05$. * denotes significance.

Table 3: Mean difference, post-hoc pairwise comparisons and 95% confidence intervals for ankle, knee, hip, pelvis & trunk kinematics. Significance level $p<0.05$.* denotes significance.

Figures

A *B*

Figure 1: A - Aircast® Airselect Elite (Walker A) with a tibial inclination angle of 4° and forefoot rocker profile 12°, and B - XLR8 Series Walker (Walker B) with a tibial inclination angle of 0° (vertically upright) and forefoot rocker profile 6°

*Table 3: Mean (SD), main effects and effect sizes for kinematic variables. Significance level p<0.05. * denotes significance.*

		WA	WB	S	p value	Effect Size
Gait speed (m/s)		1.24 (0.15)	1.23 (0.17)	1.37 (0.12)	<0.001*	0.659
SVA (°)	Maximum tibial recline angle	-16.01 (2.51)	-14.23 (2.39)	-18.21 (3.79)	<0.001*	0.452
	Maximum tibial inclination angle	50.50 (2.57)	51.55 (3.49)	53.26 (2.66)	<0.001*	0.372
	Range	66.51 (3.77)	65.77 (5.22)	71.47 (3.36)	<0.001*	0.502
Shank Angular Velocity (°/s)	Peak during early stance phase	165.78 (49.65)	184.94 (31.43)	154.33 (19.52)	0.010*	0.318
	Peak during late stance phase	222.86 (24.41)	251.10 (34.45)	200.91 (24.41)	<0.001*	0.485
Ankle Kinematics (°)	Sagittal plane angle at heel strike	7.68 (2.12)	8.02 (1.65)	6.84 (3.45)	0.385	0.062
	Plantarflexion angle during stance phase	7.08 (2.12)	7.27 (1.76)	-2.54 (2.84)	<0.001*	0.894
	Dorsi flexion angle during stance phase	11.54 (3.26)	11.88 (2.40)	17.55 (3.38)	<0.001*	0.711
	Plantar flexion angle during swing phase	6.329 (2.50)	7.00 (1.74)	-11.48 (6.34)	<0.001*	0.884
Knee Kinematics (°)	Sagittal plane angle at heel strike	8.017 (3.84)	9.51 (5.38)	5.40 (4.59)	<0.001*	0.462
	Flexion angle during stance phase	22.76 (5.68)	25.48 (5.86)	20.38 (6.27)	<0.001*	0.522
	Extension angle during stance phase	7.990(6.98)	6.483 (6.26)	7.95 (6.15)	0.141	0.122
	Flexion angle during swing phase	64.63 (6.11)	67.04 (5.64)	68.59 (5.15)	0.008*	0.274
	Maximum valgus angle	0.99 (2.29)	1.03 (2.11)	2.32 (2.48)	0.001*	0.364
	Maximum varus angle	-5.74 (3.15)	-5.68 (2.90)	-4.42 (4.54)	0.096	0.159
	Coronal plane ROM	-6.73 (2.38)	-6.71 (2.32)	-6.74 (3.30)	0.991	0.000
	Internal rotation angle	7.08 (7.08)	7.11 (7.73)	3.77 (7.22)	0.081	0.154
	External rotation angle	-10.53 (8.33)	-9.98 (8.93)	-10.17 (7.06)	0.889	0.004
	Transverse plane ROM	17.61 (5.71)	17.09 (5.72)	13.93 (4.90)	0.038*	0.196
Hip Kinematics (°)	Flexion angle	40.69 (9.64)	39.57 (10.72)	38.66 (10.00)	0.172	0.111
	Extension angle	0.49 (11.61)	-1.12 (11.62)	0.02 (10.80)	0.107	0.138
	Sagittal plane ROM	40.20 (4.93)	40.70 (4.77)	38.64 (3.97)	0.044	0.209
	Abduction angle	5.71 (2.46)	5.11 (3.37)	5.42 (3.01)	0.645	0.029
	Adduction angle	-6.11 (3.24)	-6.61 (2.71)	-9.16 (3.23)	<0.001*	0.446
	Coronal plane ROM	11.83 (2.87)	11.72 (3.00)	14.57 (3.18)	<0.001*	0.574
	External rotation angle	3.40 (10.80)	3.85 (11.07)	2.34 (10.69)	0.171	0.111
	Internal rotation angle	-8.11 (9.55)	-7.46 (9.75)	-10.18 (9.90)	0.005*	0.297
	Transverse plane ROM	11.50 (4.65)	11.31 (4.35)	12.52 (4.29)	0.041*	0.192
Pelvis Kinematics (°)	Maximum anterior pelvic tilt	18.37 (8.50)	17.526 (8.89)	16.63 (8.70)	0.079	0.156
	Minimum anterior pelvic tilt	15.04 (8.50)	13.68 (9.15)	13.36 (8.71)	0.103	0.140
	Sagittal plane ROM	3.33 (1.18)	3.849 (1.89)	3.27 (1.18)	0.103	0.140
	Maximum Downwards Pelvic Obliquity	-3.78 (2.31)	-2.98 (2.14)	-3.65 (2.19)	0.204	1.00

	Maximum Upwards Pelvic Obliquity	3.90 (2.79)	4.51 (3.12)	5.35 (2.37)	0.022*	0.225
	Coronal plane ROM	7.68 (1.93)	7.50 (2.48)	9.00 (2.22)	0.002*	0.334
	Maximum internal rotation angle	4.73 (4.04)	5.15 (4.31)	5.56 (4.00)	0.237	0.092
	Maximum external rotation angle	-5.27 (3.02)	-5.49 (3.30)	-4.41 (3.35)	0.917	0.052
	Transverse plane ROM	10.00 (3.27)	10.64 (4.05)	9.97 (3.81)	0.362	0.065
Trunk Kinematics (°)	Maximum Flexion angle	1.51 (8.23)	2.03 (8.89)	0.23 (8.27)	0.154	0.170
	Maximum Extension angle	-2.49 (7.90)	-2.52 (8.56)	-2.42 (8.12)	0.993	0.001
	Sagittal plane ROM	4.00 (1.47)	4.55 (1.92)	2.65 (0.90)	<0.001*	0.516
	Maximum right lateral flexion angle	-4.30 (2.83)	-4.32 (3.20)	-3.72 (3.55)	0.392	.089
	Maximum left lateral flexion angle	6.53 (2.72)	6.67 (3.52)	7.01 (2.94)	0.708	0.033
	Coronal plane ROM	10.83 (3.08)	10.98 (2.14)	10.73 (2.37)	0.876	0.013
	Maximum internal rotation angle	4.69 (5.37)	5.30 (4.63)	4.13 (4.13)	0.300	0.113
	Maximum external rotation angle	-5.49 (3.91)	-4.93 (4.04)	-5.22 (2.88)	0.682	0.037
	Transverse plane ROM	10.18 (3.50)	10.23 (3.30)	9.34 (2.84)	0.250	0.129

SVA – Shank to Vertical Angle
WA – Walker A
WB – Walker B
S – Shoe
ROM – Range of Motion

*Table 4: Mean (SD), main effects and effect sizes for kinetic variables (Nm/kg). Significance level p<0.05. * Denotes significance*

		WA	WB	S	p value	Effect Size
Ankle	Peak plantarflexion moment	-0.146 (0.12)	-0.173 (0.11)	-0.144 (0.10)	0.261	0.086
	Peak dorsiflexion moment	1.711 (1.35)	1.829 (1.29)	1.625 (1.07)	0.244	0.090
Knee	Peak extension moment after heel strike	-0.160 (0.13)	-0.219 (0.19)	-0.313 (0.22)	<0.001*	0.461
	Peak flexion moment during mid stance phase	0.603 (0.39)	0.704 (0.45)	0.551 (0.38)	0.004*	0.306
	Peak extension moment during late stance phase	-0.397 (0.53)	-0.494 (0.47)	-0.279 (0.41)	<0.001*	0.379
	First peak adduction moment	0.234 (0.16)	0.176 (0.12)	0.271 (0.18)	<0.001*	0.449
	Second peak adduction moment	0.374 (0.56)	0.374 (0.48)	0.429 (0.45)	0.222	0.098
	First peak internal rotation moment	0.157 (0.09)	0.157 (0.10)	0.158 (0.10)	1.000	0.000
	Second peak internal rotation moment	0.040 (0.03)	0.030 (0.03)	0.037 (0.03)	0.264	0.085
Hip	Peak flexion moment	0.669 (0.41)	0.748 (0.47)	0.647 (0.42)	0.136	0.133
	Peak extension moment	-0.668 (0.39)	-0.650 (0.39)	-0.659 (0.39)	0.897	0.007
	First peak adduction moment	0.608 (0.32)	0.566 (0.33)	0.639 (0.35)	0.090	0.109
	Second peak adduction moment	0.602 (0.40)	0.580 (0.35)	0.660 (0.35)	0.041*	0.191
	Peak internal rotation moment	0.068 (0.07)	0.078 (0.08)	0.086 (0.08)	0.310	0.072
	Peak external rotation moment	-0.222 (0.12)	-0.202 (0.13)	-0.241 (0.15)	0.026*	0.216

WA – Walker A
WB – Walker B
S - Shoe

Table 3: Mean difference, post-hoc pairwise comparisons and 95% confidence intervals for ankle, knee, hip, pelvis & trunk kinematics. Significance level $p<0.05$. Denotes significance*

			Mean Difference	p value	95% Confidence Intervals	
Gait Speed	S	WA	0.124	<0.001*	0.074	0.174
	S	WB	0.138	<0.001*	0.081	0.194
	WA	WB	-0.014	0.267	-0.012	0.039
SVA	Maximum tibial recline angle					
	S	WA	-2.206	0.014*	-3.908	-0.504
	S	WB	-3.987	<0.001*	-6.024	-1.951
	WA	WB	-1.781	0.012*	-3.107	-0.455
	Maximum tibial inclination angle					
	S	WA	2.759	0.001*	1.303	4.215
	S	WB	1.712	0.026*	0.230	3.195
	WA	WB	-1.047	0.102	-2.328	0.234
	Range					
	S	WA	4.966	0.001*	2.362	7.570
	S	WB	5.701	<0.001*	3.056	8.346
	WA	WB	0.734	0.419	-1.149	2.618
Shank Angular Velocity	Peak during early stance phase					
	S	WA	-11.448	0.304	-34.351	11.455
	S	WB	-30.609	<0.001*	-44.168	-17.050
	WA	WB	-19.161	0.015*	-34.106	-4.217
	Peak during late stance phase					
	S	WA	-21.958	0.097	-48.368	4.452
	S	WB	-50.195	<0.001*	-65.694	-34.696
	WA	WB	-28.237	0.003*	-45.117	-11.357
Ankle Kinematics	Plantar flexion angle during stance phase					
	S	WA	-9.615°	<0.001*	7.879	11.351
	S	WB	-9.809°	<0.001*	8.238	11.380
	WA	WB	-0.195°	0.724	-1.345	0.956
	Dorsi flexion angle during stance phase					
	S	WA	6.018°	<0.001*	-8.045	-3.991
	S	WB	5.678°	<0.001*	-7.367	-3.989
	WA	WB	-0.339°	0.564	-1.564	0.886
	Plantar flexion angle during swing phase					

	S	WA	-17.807°	<0.001*	14.165	21.449
	S	WB	-18.476°	<0.001*	15.064	-14.165
	WA	WB	-0.669°	0.244	-1.844	0.506
Knee Kinematics	Sagittal plane angle at heel strike					
	S	WA	-2.617°	0.005*	0.935	4.298
	S	WB	-4.106°	<0.001*	1.985	6.226
	WA	WB	-1.489°	0.033*	-2.841	-0.137
	Knee flexion angle during stance phase					
	S	WA	-2.384°	0.031*	0.251	4.516
	S	WB	-5.099°	<0.001*	2.891	7.306
	WA	WB	-2.715°	<0.001*	-3.901	-1.530
	Knee flexion angle during swing phase					
	S	WA	3.852°	0.014*	-6.803	-0.901
	S	WB	1.444°	0.246	-3.991	1.103
	WA	WB	-2.408°	0.010*	-4.161	-0.655
	Knee abduction / valgus angle					
	S	WA	1.332°	0.003*	-2.130	-0.534
	S	WB	1.289°	0.003*	-2.063	-0.515
	WA	WB	-0.043°	0.905	-0.807	0.720
Hip Kinematics	Hip sagittal plane range of motion					
	S	WA	-1.567°	0.120	-0.461	3.594
	S	WB	-2.059°	0.003*	0.835	3.283
	WA	WB	-0.492°	0.505	-2.029	1.045
	Hip adduction angle					
	S	WA	-3.044°	<0.001*	1.688	4.400
	S	WB	-2.545°	0.005*	0.912	4.177
	WA	WB	0.500°	0.402	-0.735	1.734
	Hip coronal plane range of motion					
	S	WA	2.746°	<0.001*	-3.795	-1.697
	S	WB	2.850°	<0.001*	-4.272	-1.429
	WA	WB	0.105°	0.728	-0.526	0.735
	Hip internal rotation angle					
	S	WA	-2.075°	0.030*	0.229	3.922
	S	WB	-2.726°	0.004*	1.037	4.414
	WA	WB	-.650°	0.389	-2.211	0.911

	Hip transverse plane range of motion					
	S	WA	1.016°	0.070	-2.125	0.093
	S	WB	1.214°	0.053	-2.445	0.017
	WA	WB	0.198°	0.562	-0.514	0.911
Pelvis Kinematics	Maximum Upwards Pelvic Obliquity					
	S	WA	1.450°	0.014*	-2.555	-0.345
	S	WB	0.831°	0.141	-1.972	0.310
	WA	WB	-0.619°	0.158	-1.507	0.269
	Pelvis Coronal plane range of motion					
	S	WA	1.319°	0.008*	-2.235	-0.403
	S	WB	1.501°	0.009*	-2.561	-0.442
	WA	WB	0.183°	0.578	-0.502	0.868
Trunk Kinematics	Trunk Sagittal plane range of motion					
	S	WA	-1.348°	0.005*	0.518	2.178
	S	WB	-1.901°	0.006*	0.687	3.116
	WA	WB	-0.554°	0.115	-1.269	0.162
Knee Kinetics	Peak knee extension after heel strike					
	S	WA	-.153 Nm/kg	<0.001*	0.079	0.227
	S	WB	-.094 Nm/kg	0.005*	0.033	0.154
	WA	WB	.059 Nm/kg	0.050*	0.000	0.119
	Peak flexion moment during mid-stance phase					
	S	WA	-.052 Nm/kg	0.240	-0.039	0.144
	S	WB	-.153 Nm/kg	0.010*	0.042	0.264
	WA	WB	-.101 Nm/kg	0.006*	-0.167	-0.034
	Peak extension moment during late stance phase					
	S	WA	.118 Nm/kg	0.053	-0.238	0.002
	S	WB	.215 Nm/kg	0.001*	-0.333	-0.097
	WA	WB	.096 Nm/kg	0.019*	0.018	0.175
	Peak adduction moment					
	S	WA	.037 Nm/kg	0.009*	-0.063	-0.011
	S	WB	.095 Nm/kg	<0.001*	-0.144	-0.046
	WA	WB	.058 Nm/kg	0.015*	0.013	0.103
Hip Kinetics	Peak adduction moment					
	S	WA	.058 Nm/kg	0.141	-0.138	0.022
	S	WB	.080 Nm/kg	0.009*	-0.136	-0.024
	WA	WB	.022 Nm/kg	0.447	-0.038	0.082

Peak external rotation moment					
S	WA	-.019 Nm/kg	0.178	-0.010	0.047
S	WB	-.040 Nm/kg	0.022*	0.006	0.073
WA	WB	-.021 Nm/kg	0.110	-0.047	0.005

SVA – Shank to Vertical Angle
WA – Walker A
WB – Walker B
S - Shoe