Longitudinal study of foot pressures during real-world walking as infants develop from new to confident walkers

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Abstract

Background: Onset of walking in infants leads to regular cyclic loading of the plantar foot surface for the first time. This is a critical period for evolving motor skills and foot structure and function. Plantar pressure literature typically studies gait only once walking is established and under conditions that artificially constrain the walking direction and bouts compared to how infants move in the real-world. We therefore do not know how the foot is loaded when self-directed walking is first achieved and whether it changes as walking is practiced. ***Research Question:*** How do pressures on the plantar foot in real-world walking change from new to confident walking? ***Methods:*** Fifty-seven infants participated in a two-site longitudinal study. Bespoke child-friendly spaces incorporated large pressure platforms and video. Data was collected at two milestones: new (403 days) and confident (481 days) walking. Steps were defined as walking straight or turning medially/laterally. Pressure variables were calculated for eight-foot regions and compared between milestones. ***Results:*** Confident walking resulted in more steps (median: 18 v 35) and almost twice as many turning steps. During straight-line steps, confident walking increased peak pressures in the medial heel (median: 99.3 v 106.7kPa, $p<.05$) and lateral forefoot (median: 53.9 v 65.3kPa, $p<.001$) and reduced medial toe pressure (median: 98.1 v 80.0kPa, $p<.05$). Relative medial midfoot contact area reduced (median: 12.4 v 11.2%, $p<.05$) as absolute foot contact increased. A faster transition across stance and a reduced relative contact time in the forefoot were recorded in confident walking. ***Significance:*** Pressures change rapidly as walking is initiated with significant differences in foot loading evident within an average 77 days. Importantly, these changes differ in straight and turning walking. Continued reliance on assessment of straight-line walking during early stages of ambulation likely fails to characterise 26% of steps experienced by infant feet.

Keywords

Gait; Independent Walking; Foot plantar pressure; paediatrics

Introduction

Load transmitted through the lower limb influences the shape and structure of the foot during its development (1,2). Advancement through developmental milestones leads to more foot load, more frequent loading, and greater complexity of foot movement, resulting in varied force magnitude and application. A number of researchers have described the early development of gait and its influence on the weight bearing foot (3,4). These studies have been undertaken at the onset of independent walking or once walking was established (5,6); for review see Price et al., 2017 (7).

Prior research has employed both cross-sectional (8,9) and longitudinal study designs (6,10–12). Data exists from early walkers (0-5 months of walking experience) including temporal-spatial characteristics and some quantification of limb and foot function in the form of plantar pressure, kinematics, electromyography and kinetics (3,4,13). Existing plantar pressure data collected using standardised gait protocols demonstrate that infants contact the floor in a variable pattern during their first steps, largely with the forefoot being the first point of contact with the floor (3,4). Plantar pressures are highest on the medial side of the foot, particularly the Hallux, and large contact areas are evident in the medial midfoot region due to the wide low arched foot profile (3,4,13). The advancement of walking skills is characterised by a shift in initial foot contact to the heel; initial heel contact passed from 5% to 60% of the total footfalls in eight weeks of independent walking (3). After one year of independent walking, initial contact regularly occurred with the heel (4,12). Typical patterns of walking also see a reduction in relative midfoot contact area (2.7-3.6 %) and a reduction in associated normalised forces (4.1-5.5 %) (14).

Collecting plantar pressure data using standardised gait protocols with infants is challenging. Bertsch et al., (2004) reported collecting 40-50 walking trials per participant to obtain just five steps of data (4). To overcome this unpredictability, some protocols involve leading the infant by the hand (i.e. walking supported), or encouraging them to walk in straight lines consistent with protocols in studies of adult gait (4). A small number of steps are normally analysed and irregular contacts with the floor are typically excluded (15). These approaches do not represent the real walking patterns of infants, which are known to involve short bouts of steps in multiple directions (16,17). Indeed, unpredictability in performing a task is a key feature of motor learning and its inclusion should therefore be considered an essential component to capture gait development in infants (18). The disparity between research protocols and real-world experiences of infant gait and feet undermines the generalisability of existing data and how it might inform our understanding of the association between load during very early walking and walking development. Therefore, the aim of this research was to quantify how the real-world plantar pressures on the infant foot change as walking develops, comparing plantar pressure data in new walking to confident walking when ambulating in both straight-line walking and, for the first-time, walking while turning or on a curved path.

Method

This was a two-site, four visit longitudinal study as part of the Great Foundations project (19). Ethical approval was obtained from the School of Health Science committees at the Universities of Salford (HSCR161779) and Brighton (LHPSCREC 17-11). The current method included the third and fourth visits of the longitudinal study, undertaken at the following milestones:

- Visit 3. Infant can take up to five independent steps
- Visit 4. Infant is a confident, balanced, stable walker

These visits are hereafter referred to as ‘new walking’ and ‘confident walking’ respectively.

Participants

Participants were recruited from the North West (University of Salford) and South East (University of Brighton) of England. Recruitment was undertaken within local communities and included flyer distribution to local nurseries, play centres and baby groups, social media and word-of-mouth. Parents contacted primary researchers and were screened for eligibility; criteria were born full-term, no indicators of developmental impairment and gross motor milestones attained. Exclusion criteria included referral for assessment of suspected neurological or musculoskeletal condition and family history of inherited conditions. Upon milestone achievement, parents contacted the researcher and visited within 21 days. Parental consent was gained at the start of each laboratory visit. In total 57 infants (26 Female) were recruited and completed both visits (Table 1).

TABLE 1 HERE

Testing Procedure

Data was collected within child-friendly spaces including foam flooring and toys. The floor area was approximately 4 m^2 with an embedded 1.5 x 0.5 m plantar pressure platform (resolution: 4 sensors.cm^{-2}, frequency: 100 Hz; Novel Emed-xl, Germany) and synchronised video (frequency: 50 Hz; Vicon Bonita 720c or Logitech HD Pro Webcam) (19). Infants attended the laboratory and their parent was present throughout data collection. Infants were encouraged to move around the area independently for up to 10 minutes while pressure and video data were collected synchronously in multiple 60 second trials. The infant was left to undertake self-directed tasks (e.g. playing alone or walking around) in addition to more directed tasks (e.g. carrying a small light toy such as a toy phone or small soft toy to researcher). This unconstrained walking pattern and self-directed object carrying were enabled to increase the external validity of the data (16,20).

Data Treatment

Pressure data was processed using Emed® software (Novel gmbh, Munich, Germany). All steps were extracted if the foot contact was within the platform area and foot contact to foot off were visible. Visual observation of video data was used to define tasks:

- Walking straight: infant walking in a line without changing direction
- Walking curved or turning walking: infant walking while changing direction, following a curved path or turning.
- The steps defined as walking while turning were then further defined based on the direction of the turn relative to the central midline along the longitudinal axis of the foot (Figure 2):
    - Medial turning: towards the medial side of the foot being placed/towards the opposite foot.
    - Lateral turning: towards the lateral side of the foot being placed/away from both feet.

Data from 10 infants was used to determine the reliability of step extraction for walking straight or walking turning, with high reliability between two researchers (AMS and EM) ($ICC_{3,1}$ range 0.77-0.99, median 0.98).

Data Analysis

Descriptive step pattern

A frequency analysis recorded the number of steps of each type that infants took at each walking milestone. This included a count of the number of walking straight steps, turning medial and lateral. In addition, the number of infants undertaking each walking type at each milestone was recorded.

Pressure analysis

One foot for each infant was included in the analysis to maintain statistical independence (21) based on randomization at the first visit of the larger longitudinal study (19). Eight-region personalised masks were created for each infant for each visit (Figure 1), increasing resolution and enabling any potential shift in medio-lateral loading of the foot to be identified. To ensure relevance to the age group, the masks were created based on interpretation of infant radiographic data from literature (22,23).

FIGURE 1 HERE

Percent masks were created based on proportion of feet length and width using 'Creation of any masks' software (Novel gmbh, Munich, Germany) for each infant and milestone on the pressure step which most closely matched the foot length of that infant for that milestone. This process improved the ability of the software to apply the mask. All extracted steps were grouped by walking task (straight, medial turning and lateral turning) and visit (new and confident walking), and the personalised mask automatically applied (this failed for only 39 of the 3396 steps, 1%). Variables were calculated for each task and each foot region for usable steps: peak pressures, absolute and percentage of contact area and absolute and percentage of contact time ('Groupmask evaluation' software, Novel gmbh, Munich, Germany).

Statistical Analysis

Statistical testing was undertaken in SPSS (Version 25, IBM Statistics, USA). Normality was tested for all variables utilising Shapiro-Wilk tests in addition to visual inspection of histograms and stem and leaf plots. Data were non-parametric and visual inspections of histograms and skewness/kurtosis values indicated data was skewed. Therefore, the sign test was chosen to compare straight line steps, medial turn steps and lateral turn steps between new and confident walking, to address the research question.

Results

Descriptive step pattern

For new walking, we captured a median of 18 steps (IQR 20) per infant and a median of 35 steps (IQR 20) for confident walking. The total number of walking straight (1117 to 16460) and walking turning (102 to 384) steps across all infants increased for the confident versus new walking, and the proportion shifted from approximately one in nine steps (11%) being turning or on a curved path to one in four (26%). From new to confident walking the number of medial turning steps increased from 46 to 178 and for lateral 56 to 206 respectively. The number of infants undertaking any steps on a curved path also increased from 31 to 53 out of 57 during confident walking. Twenty-two of the infants undertook medial turning steps when new walkers and only 16 took lateral turning steps. Once confident walkers these numbers increased to 45 and 46 respectively from the total number of 57 infants.

Peak pressure

Peak pressure in straight walking increased in the medial heel and lateral forefoot in the confident walking steps (Table 2). The pressure in the medial toes reduced. In the walking turning data, there were no significant changes between new and confident walking when turning toward the medial and lateral sides.

TABLE 2 HERE

Contact area

Lateral forefoot relative contact area increased in confident walking in a straight line (Table 3). Medial midfoot contact area percentage decreased in the confident walking steps, alongside a small non-significant decrease in the absolute contact area (Table 3). Contact area for all other regions aside from the medial heel and lateral toes increased in the confident walking data compared to the new walking data in walking straight. In lateral turning walking an increase in medial heel absolute contact area was recorded in confident walking, however this was not significant as a relative change.

TABLE 3 HERE

Contact time

Contact time as a percentage of stance in the medial midfoot in confident straight walking (73.2%) was lower than that in new walking (75.4%) (Table 4). Reductions in the lateral and medial forefoot and toes were also significant in confident walking steps. Absolute contact time variables demonstrated significant reductions of more than 110 ms in median values in all foot regions in straight walking steps in the confident walking steps (Table 4). Turning towards the medial side resulted in lower absolute stance times in the medial and lateral forefoot in confident walking. No other significant differences between median values were evident in walking turning steps in the confident walking steps, however 75th percentile values and inter-quartile ranges reduced substantially for the later milestone.

TABLE 4 HERE

Discussion

Capturing plantar pressure during more realistic gait in infant walking provides a unique data set. This paper provides the first real-world measure of load being applied to the infant foot as very early stages of walking are practised and helps inform our understanding of how the demands on the foot change as walking develops. This paper adds to the sparce data quantifying plantar pressures as infants start walking by providing a longitudinal data set defined by milestone. It is the first to report longitudinal plantar pressure data in infants who recently commenced walking for different tasks of walking in a straight line and walking on a curved path or while turning. Consistent with typical milestone attainment (24) the infants in this study started walking at 389 days (12.5 months; range 8.5 to 17.0).

Data collected from infants walking in a straight line, which is the focus of all previous literature, has failed to characterise up to 26% of the steps the infants take. Infants took more steps once walking confidently and a higher proportion of these involved turning (from 1 in 9 to 1 in 4). Twenty-two more infants undertook some curved walking over the pressure platform once confident than had during their new walking. The number of lateral turns in new walkers was also 1.2 times the number of medial, a proportion which remained consistent in confident walking despite the increase in the number of infants turning and the number of steps they took. Increasing the number of turning steps is consistent with developmental literature and attributable to advancement in infant capability to undertake more steps for exploration in their environment (16). The reduction in the magnitude of both the 75th percentile and inter-quartile range of the curved walking absolute contact times in confident walking demonstrate that the longest stance times in our infants reduced. This further supports the premise that there is an increase in capability to effectively undertake curved walking with increased walking experience. This is supported by data which shows us that longer paths in infant walking (4 plus steps) are more likely to be curved than straight (18,25). The number of curved path walking steps being undertaken in the confident walkers is justification for our methods.

Confident walking demonstrated different foot pressure compared to new walking steps despite being an average of just 77 days later. In the new walking steps, the heel (99.3, 98.2 kPa) and medial toes (98.1 kPa) had the highest pressures. This changed in confident walking, with heel pressure increasing slightly (106.7 kPa, $p<.05$; 104.4 kPa, $p>.05$) and medial toe reducing significantly (80.0 kPa, $p<.05$). This shift in pressures has previously been attributed to a need to increase stability by increasing contact area and shifting weightbearing to an area of the foot that enables more muscular control (3). However, our data does not support a reduction in contact area as the infants became more confident, though small foot growth between milestones would have influenced this. Bertsch et al. reported that a shift in peak pressure from the hallux to the heel occurred sometime between 3 and 6 months after walking onset (4). In the existing study the heel becoming the foot area bearing highest pressures was evidenced in a mean of only 2.5 months (maximum 4.8 months) from walking onset. Without considering the individual differences as opposed to the mean values, it is hard to know how many individuals demonstrated this shift and at which age; the average peak pressure data only gives us an overall indication of how the plantar pressure is evolving in a group of infants. Other experimental variations may account for differences between studies; Bertsch et al (2004) excluded irregular walking patterns, adopted a mid-gait protocol and restricted infants walking in a straight line. This may have led to faster walking speeds

(although not reported in either study) and therefore, potentially elevated pressures compared to the current study.

There was a significant increase in forefoot pressure with the development of walking experience. Peak pressure at the lateral ($p < .001$) and medial ($p > .05$) forefoot was greater for straight walking steps in confident walkers versus new, consistent with the previous findings (4). In a cross-sectional study Hallemans et al., reported a reduction of peak pressure under the first metatarsal head with walking experience ranging from a few days to eight weeks (3). This was attributed to the transition of initial foot contact from the toe region to predominantly flat foot and heel contact. As we saw infants an average of 15 days after they first walked 3-5 steps we may have missed this very early and likely rapidly changing phase. The largest reduction in first metatarsal head pressure has been identified within two weeks of first steps (3).

Changes in contact area over time were evident within our infants. There was an overall increase in absolute contact area for all foot regions apart from the midfoot when walking straight. This reflects an increase in absolute foot size (foot length increased an average of 0.5 cm). The sizes and this increment over the average 77 days between the two visits in this study are both consistent with existing growth data in similar cohorts (15). Despite the overall increase in foot size, medial midfoot contact area reduced in relative ($p < .001$) and absolute ($p > .05$) values during straight walking. Existing literature points to a 2.7-3.6% (4,14,15) reduction in midfoot contact area in infancy, (up to 2 years) compared to a median reduction of 1.2% in the medial midfoot in confident walking in the present study. As discussed, this smaller change may be due to the two milestones being closer together in this research than prior studies. It may also be that walking with less instruction and direction (even when only considering the straight-line data) may have increased the midfoot contact as slight variations in foot contact would be adopted during more variable ambulation. Whilst we divided the midfoot into lateral and medial regions, a notable difference in methodology to previous research, this does not account for this smaller reduction. Coupled with the reduction in medial midfoot contact area, was a reduction in relative and absolute contact time, without a significant change in plantar pressure. The changes in midfoot contact area were not evident in the turning walking. However, an increase in medial heel contact area when turning laterally was recorded.

As the infants progressed from new to confident walking proportionally less time was spent with the medial midfoot, forefoot and toes in contact with the floor. There were large reductions in absolute contact time in straight-line walking. This represents a reduction in concurrent contact with the floor of multiple regions in stance and a faster transition to foot off. This may also relate to the transition to a rearfoot contact pattern with the floor, as opposed to a flat foot contact (3). Relative data identified no difference in heel contact time duration, despite a nearly 200 ms reduction in average absolute values. Walking turning temporal data changed less with the maturation of gait to confident walking however contact times became more consistent across infants. Steps turning medially reduced significantly in their absolute contact time in both the medial and lateral forefoot (with slight reductions in the relative values). This was not mirrored for lateral turning, however this data demonstrated far higher inter-quartile ranges, particularly in new walking, and had a lower N of 14 for statistical comparison.

Despite the novelty of this work there are limitations to consider. The descriptive step count comparisons are limited by their inclusion of only the steps the participants took on the pressure platform and therefore not being normalised to the distance or the time of the entire trial, both of which were also variable between infants and milestone. This limitation stems

from us allowing the child to self-determine most of their movements and therefore producing externally valid data relating to plantar foot loading. We analysed our medial and lateral turning steps separately from our straight-line walking steps and from each other. However, we did not further subdivide the steps based on the severity of the turn or the phase in which the turn the steps occurred (26), which will require further exploration. A further limitation involves the data processing where the foot was regionalised using a mask to compare values across milestones; future work will look to implement methodologies such as Statistical Parametric Mapping which remove assumptions the masking approach requires, such as statistical independence (27,28).

Conclusions

This research aimed to describe real-world plantar pressures as infants developed from new to confident walkers, using a protocol which more closely resembles their typical foot loading behaviour. Confident walking produced substantially more steps from infants and a higher proportion of steps involving turning. A faster transition of pressure across the foot from touchdown to toe-off was evident in confident walkers when straight-line walking. Fewer significant differences were evident in turning steps but contact time in the forefoot reduced in medial turning steps. The increased proportion of steps and statistical outcomes from straight-line walking data differ to that during turning walking and mature differently. This means reliance on assessment of straight-line walking during the very early stages of ambulation likely fails to characterise 26% of steps experienced by infant feet.

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Figure Captions:

Figure 1. Pressure mask applied to example data displaying the percentages of foot length and width used to define the anatomical regions.

Figure 2. Definition of turning steps as medial or lateral based on the direction of the turn relative to the central midline along the longitudinal axis of the foot.

Figure 3. Significant changes in peak pressure, contact area and contact time from new to confident walking with direction of changes denoted by arrows. Grey arrows indicate absolute changes and black relative changes.

Table 1. Descriptive information for participants at each of the two milestones.

	New walking				Confident walking				*P*
	Min	Mean	SD	Max	Min	Mean	SD	Max	
Age at visit (days)	278.0	403.4	55.3	527.0	333.0	480.7	66.2	615.0	<.001
Age at milestone (days)	263.0	388.9	55.4	519.0	325.0	465.5	64.8	597.0	<.001
Days since milestone	5.0	14.5	4.9	21.0	3.0	15.1	5.5	21.0	NT
Mass (kg)	7.5	10.1	1.3	13.8	26.0	77.3	28.3	147.0	<.001
Height (cm)	68.5	74.5	3.0	81.8	8.0	10.9	1.4	14.0	<.001
Foot length (cm)	9.6	11.5	0.9	13.5	69.3	78.0	3.6	85.0	<.001
Foot width (cm)	4.4	5.1	0.4	6.0	10.0	12.0	0.9	13.6	.019

P value determined by statistical comparison using Wilcoxon-signed rank test where NT denotes not tested.

Table 2 Median and inter-quartile range of peak pressure (kPa) for new walking and confident walking for 8 masked regions in both walking straight and walking turning steps.

		New Walking									Confident Walking								
		Walking Straight (N = 57)			Medial Walking Turning (N = 22)			Lateral Walking Turning (N = 16)			Walking Straight (N = 57)			Medial Walking Turning (N = 45)			Lateral Walking Turning (N = 46)		
		25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th
HEEL	M	86.5	99.3*	122.7	69.5	77.9	121.7	62.7	91.3	103.1	90.6	106.7 *	122.6	78.8	100.0	126.8	74.8	100.0	117.2
	L	87.1	98.2	114.8	70.0	87.5	116.3	65.4	83.1	103.3	90.0	104.4	116.1	76.8	91.7	109.4	81.1	97.3	115.8
MIDFOOT	M	64.1	72.3	78.5	53.8	67.5	80.6	53.1	65.1	78.8	63.5	69.5	78.3	60.0	66.7	79.2	63.6	72.1	80.0
	L	67.6	75.0	81.9	55.0	70.0	80.0	65.6	73.8	84.2	72.0	77.2	81.9	65.0	71.3	82.1	68.3	75.0	84.6
FOREFOOT	M	56.4	72.0	84.7	50.8	62.5	85.6	40.0	52.1	64.4	63.1	81.8	94.3	56.0	76.9	106.7	45.0	51.3	66.0
	L	45.5	53.9**	60.2	40.0	51.3	70.0	37.0	55.0	68.8	58.2	65.3**	74.1	45.0	52.5	65.4	43.5	53.0	70.0
TOES	M	81.9	98.1*	120.3	70.0	86.3	130.0	54.7	62.6	80.8	70.2	80.0*	107.5	65.2	75.0	109.2	50.1	64.1	75.3
	L	26.7	34.8	43.6	20.6	35.0	48.5	20.9	36.3	62.5	25.9	33.0	41.2	23.1	30.8	46.7	19.7	29.4	40.0

Sign test for medial turning steps N = 20, sign test for lateral turning steps N = 14. Where M = medial, L = lateral and N denotes the number of participants with steps included in each task and ** p< .001, * p <.05.

Table 3 Median and inter-quartile range of contact area relative (percentage of whole foot contact area) and absolute (cm^2) values for new walking and confident walking for 8 masked regions in both walking straight and walking turning steps.

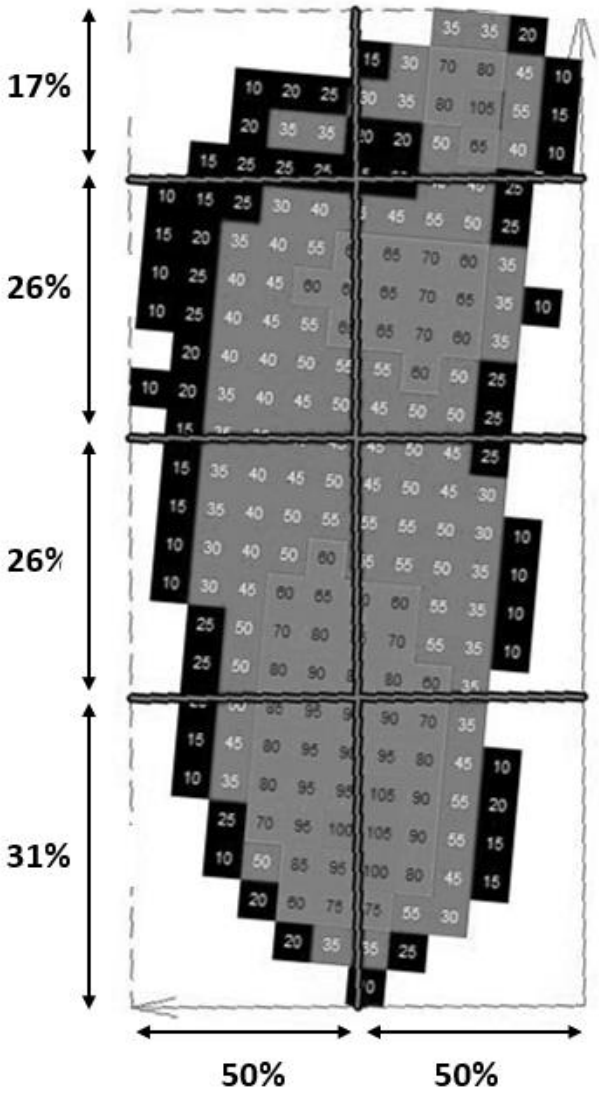
			New Walking									**Confident Walking**								
			Walking Straight (N = 57)			Medial Walking Turning (N = 22)			Lateral Walking Turning (N = 16)			Walking Straight (N = 57)			Medial Walking Turning (N = 45)			Lateral Walking Turning (N = 46)		
			25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th
Relative values (%)	**HEEL**	M	11.7	13.0	14.3	10.9	13.3	14.6	10.3	12.2	14.5	11.3	12.4	13.2	12.2	13.2	14.8	11.2	13.0	14.8
		L	11.5	12.8	13.5	10.7	12.9	14.1	12.1	13.3	15.5	12.2	13.1	13.8	11.7	12.4	13.2	11.6	13.4	14.4
	MIDFOOT	M	10.9	12.4*	13.9	10.9	13.5	14.4	8.5	11.6	13.2	9.8	11.2*	12.7	10.6	12.7	14.1	9.1	11.9	14.1
		L	14.7	15.6	16.6	13.9	15.6	16.9	14.9	15.8	16.4	15.2	16.2	17.1	14.2	15.4	16.6	14.5	15.8	17.1
	FOREFOOT	M	15.0	15.6	16.7	14.5	15.8	16.8	14.5	15.4	17.1	15.2	16.1	16.5	14.7	16.3	17.1	14.4	15.6	16.4
		L	15.9	16.7*	17.7	15.5	16.7	17.8	15.7	17.4	18.6	16.3	17.3*	18.1	15.3	16.4	17.6	15.8	16.9	18.1
	TOES	M	9.6	10.2	10.6	8.7	9.7	10.5	8.1	10.1	11.2	9.4	10.0	10.7	8.4	9.4	10.2	8.5	9.9	10.7
		L	3.5	4.2	5.1	2.9	4.4	6.8	3.3	5.1	6.4	3.5	4.5	5.4	3.2	4.7	5.8	3.0	4.7	5.7
Absolute values (ms)	**HEEL**	M	5.3	6.0	6.7	5.3	5.8	6.8	4.8	5.8*	6.2	5.4	6.2	6.9	5.4	6.4	7.0	5.1	6.0*	6.9
		L	5.2	5.8**	6.4	4.9	5.9	6.4	5.3	6.2	6.9	5.9	6.4**	6.9	5.3	5.7	6.4	5.5	6.0	7.1
	MIDFOOT	M	5.0	5.8	6.5	4.8	5.9	6.8	3.5	5.7	6.0	4.6	5.5	6.4	4.7	5.9	6.8	4.3	5.4	6.8
		L	6.7	7.2**	8.0	6.0	7.0	8.0	6.6	7.0	7.9	7.5	7.9**	8.7	6.8	7.3	7.8	6.6	7.3	8.3
	FOREFOOT	M	6.6	7.2*	7.9	6.3	6.9	8.3	6.0	7.0	8.2	6.9	7.9*	8.7	6.8	7.7	8.3	6.3	7.2	8.3
		L	7.1	7.8**	8.4	6.7	7.7	8.7	6.9	7.9	8.6	8.0	8.4**	9.2	6.8	7.8	8.6	7.2	8.0	8.9
	TOES	M	4.3	4.7*	5.1	3.8	4.5	4.9	3.5	4.3	4.9	4.5	5.0*	5.5	3.9	4.3	5.1	3.7	4.6	5.3
		L	1.7	2.0	2.4	1.2	2.2	3.0	1.3	2.3	3.0	1.7	2.1	2.7	1.5	2.1	2.8	1.3	2.2	2.8

Sign test for medial turning steps N = 20, sign test for lateral turning steps N = 14. Where M = medial, L = lateral and N denotes the number of participants with steps included in each task and ** p< .001, * p <.05.

Table 4 Median and inter-quartile range of contact time relative (percentage of whole foot stance time) and absolute (ms) values for new walking and confident walking for 8 masked regions in both walking straight and walking turning steps.

			New Walking									**Confident Walking**								
			Walking Straight (N = 57)			Medial Walking Turning (N = 22)			Lateral Walking Turning (N = 16)			Walking Straight (N = 57)			Medial Walking Turning (N = 45)			Lateral Walking Turning (N = 46)		
			25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th
Relative values (%)	**HEEL**	M	65.8	69.6	73.6	62.1	68.9	83.6	69.9	80.4	83.3	62.1	68.0	72.3	69.1	76.6	80.5	73.0	79.5	83.8
		L	63.7	69.4	72.2	59.9	67.2	77.8	68.6	80.0	82.2	64.0	69.0	73.2	66.4	74.7	77.8	73.0	80.0	84.4
	MIDFOOT	M	71.7	75.4*	78.8	69.3	76.2	82.7	76.4	82.3	84.2	70.1	73.2*	76.7	72.4	77.4	82.4	77.7	81.3	85.7
		L	72.5	76.6	82.1	70.2	75.1	86.2	81.8	85.6	88.4	73.5	77.0	79.9	73.0	78.5	83.4	79.6	83.5	87.6
	FOREFOOT	M	86.4	90.8*	93.1	79.0	91.1	95.8	79.2	89.3	94.9	82.2	86.9*	89.5	80.4	87.8	94.2	76.8	86.9	93.4
		L	84.2	87.3*	90.7	80.7	87.4	90.9	82.9	91.6	97.4	79.6	84.1*	87.7	73.8	85.0	90.7	79.5	89.1	92.1
	TOES	M	66.2	76.9**	84.9	66.8	89.0	95.6	65.0	73.4	92.2	58.7	66.0**	76.4	64.6	76.9	85.4	67.9	78.9	87.8
		L	48.7	59.9*	68.4	42.4	75.4	87.0	56.9	64.9	83.6	40.8	55.2*	63.7	38.7	56.2	65.3	51.1	62.3	73.9
Absolute values (ms)	**HEEL**	M	457.3	646.3**	901.4	532.5	637.5	1128.8	614.6	710.0	1380.0	372.2	469.7**	565.4	523.1	662.5	741.1	428.1	570.0	760.4
		L	478.4	628.3**	854.0	543.5	627.5	1011.3	623.1	719.2	1298.8	394.6	473.4**	574.8	457.5	607.5	710.0	475.6	585.3	828.8
	MIDFOOT	M	518.2	645.6**	872.5	575.7	735.0	978.8	622.1	740.2	1433.8	407.9	511.5**	620.0	510.3	630.0	738.5	491.2	596.3	760.5
		L	554.0	656.7**	894.0	624.3	730.0	973.8	687.5	792.2	1442.5	459.4	537.1**	627.5	497.9	630.0	745.8	510.0	607.9	842.5
	FOREFOOT	M	599.0	750.0**	1166.0	628.3	855.0*	1172.5	595.4	762.5	1523.8	497.7	556.6**	680.9	550.0	730.0*	914.3	518.8	600.0	761.2
		L	615.8	738.8**	1088.6	620.8	875.0*	1125.0	657.9	817.5	1538.8	489.7	557.5**	656.1	520.4	670.0*	851.0	543.8	625.8	819.5
	TOES	M	503.6	659.4**	1041.1	545.0	855.0	1371.3	497.7	719.4	1481.3	371.9	452.1**	616.3	455.3	606.0	805.0	482.5	569.2	695.5
		L	404.3	505.6**	780.3	315.8	707.5	1010.0	445.0	535.0	1425.2	261.8	372.5**	490.7	260.0	464.0	712.8	346.7	483.5	585.0

Sign test for medial turning steps N = 20, sign test for lateral turning steps N = 14. Where M = medial, L = lateral and N denotes the number of participants with steps included in each task and ** p< .001, * p <.05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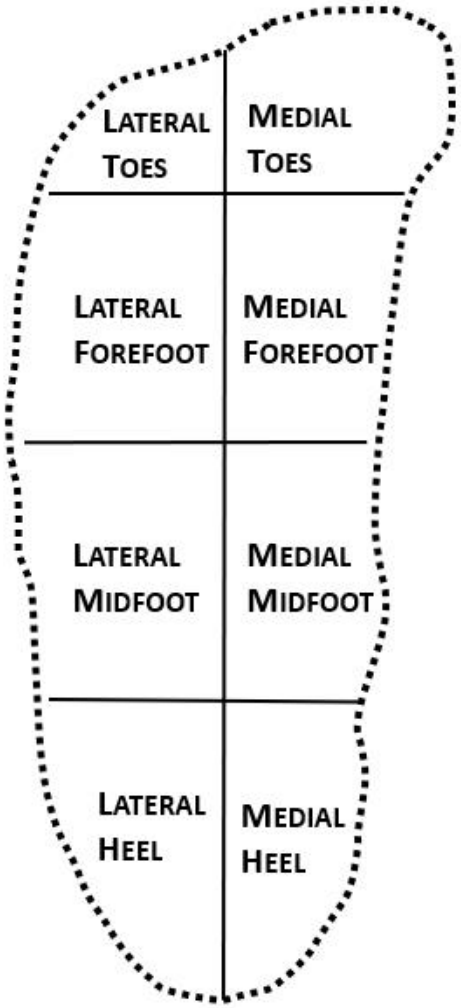
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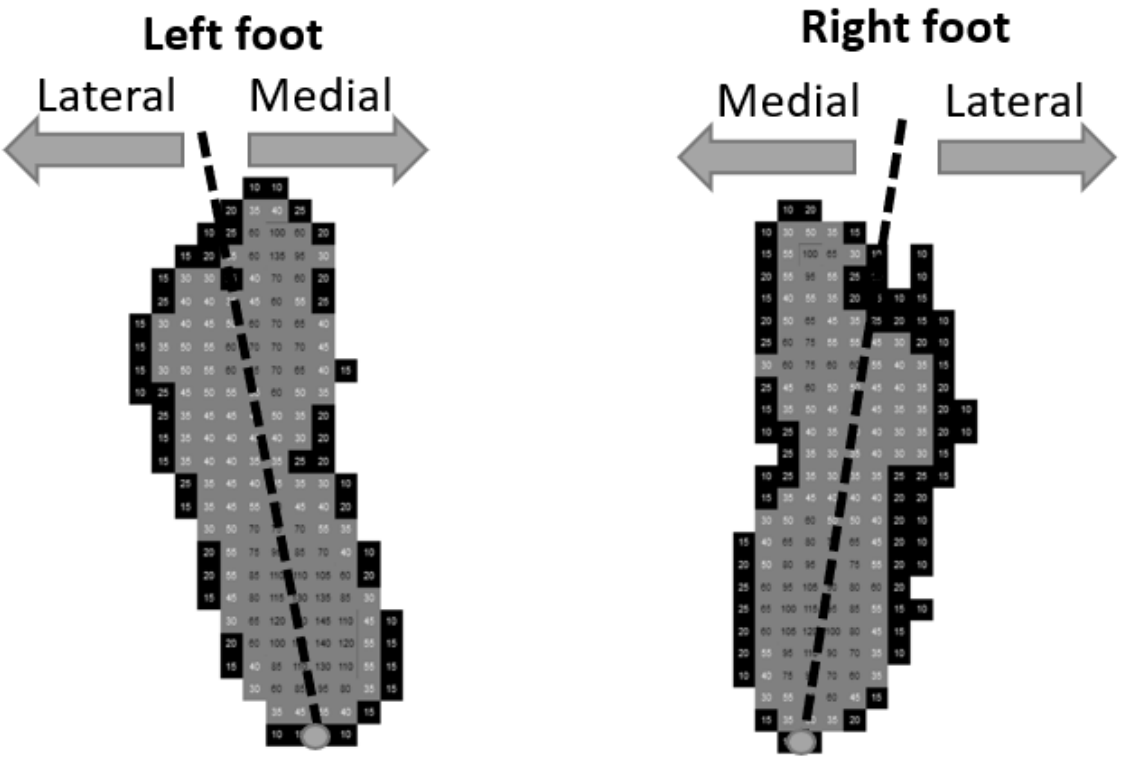

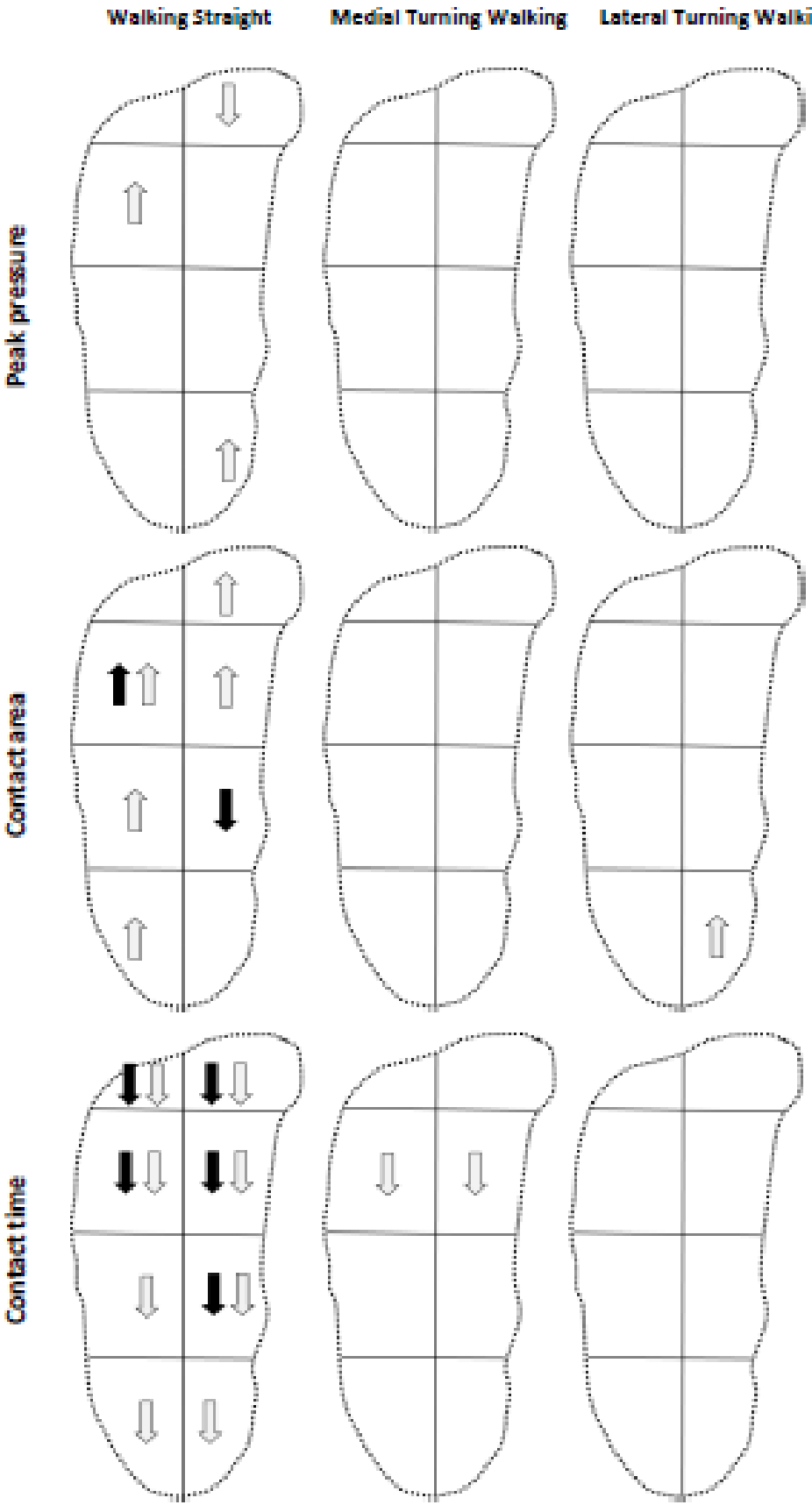
Walking Straight
Medial Turning Walking
Lateral Turning Walking
Peak pressure
Contact area
Contact time