Title: The between-day repeatability, standard error of measurement and minimal detectable change for discrete kinematic parameters during treadmill running.

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Abstract

Background: Kinematic parameters of the trunk, pelvis and lower limbs are frequently associated with both running injuries and performance, and the target of clinical interventions. Currently there is limited evidence reporting the between-day repeatability of discrete kinematic parameters of the trunk, pelvis and lower limbs during treadmill running.

Research question: What is the between-day repeatability, standard error of measurement and minimal detectable change of discrete kinematic parameters of the trunk, pelvis and lower limbs during treadmill running?

Methods: 16 healthy participants attended two kinematic data collection sessions two weeks apart. Three-dimensional kinematic data were collected while participants ran on a motorised treadmill at 3.2m/s. The interclass correlation coefficient, standard error of measurement and minimal detectable change were calculated for discrete kinematic parameters at initial contact, toe off, peak angles and joint excursions during the stance phase of running.

Results: Good to excellent repeatability with low standard error of measurement and minimal detectable change values were observed for sagittal and frontal plane kinematics at initial contact (Range: ICC, 0.829 - 0.941; SEM, 0.6°- 2.6°; MDC, 1.5°- 7.2) and peak angles during stance (Range: ICC, 0.799 – 0.946; SEM, 0.6°- 2.6°; MDC, 1.7°- 7.1°). Peak transverse plane kinematics of the hip (ICC, 0.783; SEM, 3.2°; MDC, 8.7°) and knee (ICC, 0.739; SEM, 3°; MDC, 8.4°) demonstrated moderate between-day repeatability with large SEM and MDC values. Kinematics at toe off demonstrated the lowest ICC values and largest measurement errors of all parameters (Range: ICC, 0.109 – 0.900; SEM, 0.8°- 5.7°; MDC, 2.5°- 15.7°).

Significance: This is the first study detailing the measurement error and minimal detectable change for discrete kinematic parameters of the trunk and pelvis during treadmill running. The reported values may provide a useful reference point for future studies investigating between-day differences in running kinematics.

Keywords: Running; Gait; Kinematics; Repeatability

1. Introduction:

Running kinematics are frequently cited as a factor influencing both running related injuries and running performance. Using 3D motion analysis technology, several studies have reported discrete kinematic parameters of the trunk, pelvis and lower limbs to be associated with running injury [1, 2] and performance [3-5]. Consequently, there is increasing research focus investigating whether clinical interventions can effectively target stance phase running kinematics [6-9].

Using test-retest designs, several studies have investigated the effects of clinical interventions on running kinematics. These studies have reported changes in kinematic parameters, including reductions in peak trunk forward lean and contralateral pelvic drop, hip adduction and hip internal rotation following step rate retraining [7, 8, 10], as well as reductions in knee abduction excursion following neuromuscular conditioning exercises [9]. Although these findings appear promising, the observed differences are often small and therefore there is a need to establish whether kinematic differences represent true intervention effects, or are instead, the result of between-day variability in kinematic measurement.

Although discrete trunk and pelvis kinematics have been targeted through gait interventions [7, 8], no study has reported the repeatability of these parameters during treadmill running. Instead, current literature has focused upon kinematic patterns of the hip, knee and ankle [11-13]. Of these studies, many utilise statistics such as the interclass correlation coefficient [12-14] and the coefficient of multiple correlation (CMC) [11, 15, 16]. Although such data provide a statistical measure for the interpretation of the repeatability of measurements, the statistical values are of limited clinical value; as they do not provide estimates of the measurement precision or the degree of change required to represent a true between-day change in kinematics [17]. In contrast, the minimal detectable change (MDC) is considered to represent the degree of change representative of a true change and is expressed in the same measurement unit as the measurement itself (degrees of movement) [18, 19]. Therefore, reporting the MDC of discrete kinematic parameters during running, may provide a useful reference point to assist the interpretation of between-group and post intervention kinematic differences.

Based on current gaps within the repeatability literature, the aim of the present study was to investigate the between-day repeatability, standard error of measurement and minimal detectable change of discrete kinematic parameters of the trunk, pelvis and lower limbs during treadmill running.

2. Methods

2.1. Participants & procedures

A total of 16 healthy participants were included within this study (Table 1). Participants were recruited via poster advertisements at local running clubs and sports injury clinics. All participants were considered experienced runners with more than 2 years running experience, running a minimum of three times per week. Participants were self-reported regular road runners comfortable with treadmill running. Exclusion criteria included a current running related injury, or injury sustained within the last 18 months. Injury was defined as any musculoskeletal pain causing a stoppage or restriction to run volume, duration or speed for a minimum of 7 days or three consecutive scheduled training sessions, or that required the runner to consult a physician or health care professional [20]. All participants provided written informed consent prior to participation and ethical approval was obtained via the local ethics committee.

Participants attended two data collection sessions two weeks apart following the same data collection procedures. At each testing session, three-dimensional kinematic data were collected using a 12 camera Qualysis Oqus system sampling at 240hz (Gothenburg, Sweden) while participants ran on a motorised treadmill (Sole Fitness, F63, USA) at 3.2m/s wearing their own running shoes. Prior studies have reported no difference in kinematic repeatability when using self-selected or standardised running speeds [21]. Therefore a standardised running speed of 3.2m/s was selected, as this speed was considered similar to average training paces commonly encountered by recreational runners [22] and used in prior kinematic studies [2, 23].

Participants performed a 5-minute warm up, after which 30 seconds of kinematic data were collected in order to obtain a minimum of 10 consecutive footfalls. To avoid the effects of intertester differences in marker application the lead researcher, a qualified physiotherapist with more than 7 years' experience delivering gait analysis, applied all markers [24].

2.2. Derivation of kinematic data

Anatomical segments of the trunk, pelvis, bilateral thighs, shank and feet were tracked using retroreflective markers attached to anatomical landmarks using a protocol described previously [11, 25]. Specifically, the trunk segment was tracked using a rigid cluster containing 3 markers attached to the sternum with an anatomical reference frame defined using markers attached to the suprasternal notch, xiphoid process, 7th cervical vertebrae (C7) and 6th thoracic vertebrae (T6). For this segment, the z-axis was defined as a line connecting the midpoint between the suprasternal notch and C7, and the midpoint between the xiphoid process and T6. The x-axis was defined as the perpendicular to the plane formed between the suprasternal notch and C7, and the midpoint between the xiphoid process and T6. The y-axis was directed anteriorly, perpendicular to the x and z-axis.

For the pelvis segment, tracking markers were placed bilaterally on the anterior superior iliac spines (ASIS) and posterior superior iliac spines. To define the segment, static markers were positioned mid-way along the iliac crest directly above the greater trochanter. The joint centre origin was defined as the point midway between the two iliac crest markers. The z-axis was directed vertically, the x-axis directly from the origin to the right iliac crest marker and the y-axis directed anteriorly, perpendicular to the z and x-axis.

Rigid thigh and shank clusters containing four markers were placed laterally over the thigh and shank segments and secured using adhesive tape and elasticated bandages. Anatomical reference frames for the thigh/shank segments were defined using markers attached to the greater trochanters, lateral/medial femoral condyles and lateral/medial malleoli. The anatomical coordinate frame for the thigh was oriented with the z-axis aligned with the long axis of the bone, from the hip joint centre (defined using a regression equation [26, 27] and the knee joint centre (mid-point of the epicondyle markers). The x-axis was directed right, perpendicular to the z-axis and the y-axis anteriorly, perpendicular to the x and z-axis. The shank coordinate frame was defined similar to the thigh segment, using the lateral/medial femoral condyles and malleoli markers.

The foot segment was defined similar to previous studies [28] with markers placed directly onto the shoe at the heel, the base of the 5th metatarsal, 1st metatarsal and head of the 2nd metatarsal. A virtual foot segment was used defining the neutral joint position as a flat foot with a vertical shank segment. The ankle joint origin positioned at the midpoint of the lateral and medial malleolus markers, z-axis oriented vertically from the origin, the x-axis pointing towards the right along a line through the malleolus markers and the y-axis pointing anteriorly, through the central points between the medial/lateral malleolus and the 1st/5th metatarsal markers.

2.3. Data Processing

Raw kinematic data were low pass filtered at 10Hz. Joint angles were calculated between adjacent segments for the ankle, knee and hip and segmental angles calculated relative to the laboratory system for the pelvic and trunk segments. Kinematic data were calculated using a six degrees of freedom model using the commercial software Visual 3D (C-Motion) in accordance with prior publications [11, 25]. For these calculations a cardan angle sequence was used to define joint orientation using a right-hand rule and joint angle conversion of x-y-z. With x = flexion/extension, y = abduction/ adduction, z = internal/ external rotation. These data were then exported to Matlab for further processing.

Gait events were defined using a kinematic approach [29] in which initial contact was defined as the first peak in vertical acceleration of either the heel or any of the metatarsal markers. Toe-off was identified as the vertical jerk peak of the 2nd metatarsal marker [29]. Using these events, each kinematic signal was segmented into a minimum of 10 consecutive gait cycles and an ensemble average created. Ten consecutive gait cycles were selected based on prior work, suggesting a minimum of 5 gait cycles is required to obtain reliable kinematic data [16] and to replicate methods utilised in prior repeatability studies [11].

Foot strike patterns of each participant were determined based on the kinematic waveforms of the ankle joint. Where the ankle demonstrated an immediate movement into plantarflexion, participants were classified as having a rearfoot strike (RFS), participants demonstrating immediate ankle dorsiflexion were classified as a forefoot strike (FFS). Overall, there was a total of 6 FFS runners and 10 RFS runners. Specific kinematic parameters were derived from the ensemble average curves, including sagittal, frontal and transverse plane angles of the trunk, pelvis, hips, knees and ankles at initial contact and toe-off, peak angles and total joint excursion. Peak angles were defined as the maximum joint angle between initial contact and toe off, while joint excursions were defined as maximum angle minus the angle at initial contact.

2.4. Statistical Analysis

ICC estimates and their 95% confidence intervals were calculated using SPSS (IBM Statistics v23) (SPSS Inc, Chicago, IL) using a two-way mixed effects model, mean of k measurements with absolute agreement [30]. Interclass correlation coefficient provides a value ranging between 0 (indicating no reliability) to 1 (indicating perfect reliability) [18, 31]. Values of <0.5, 0.5-0.75, 0.75-0.9 and >0.9 were interpreted as poor, moderate, good and excellent respectively [30]. In order to aid the clinical interpretation of between-day differences in running kinematics the standard error of measurement (SEM) and minimal detectable change (MDC) were calculated as described in previous publications [19, 32]. Specifically, the SEM was calculated as $SD*\sqrt{(1 - ICC)}$ and the MDC was calculated as $SEM*1.96*\sqrt{2}$.

3. Results

Kinematic data at initial contact, peak angles, joint excursions and angles at toe off; along with the ICC values, 95% confidence intervals, SEM and MDC can be viewed in tables 2, 3, 4 and 5.

3.1. Initial Contact

At initial contact, frontal and sagittal plane kinematic parameters of the trunk, pelvis, hip, knee and ankle were found to demonstrate ICC values ranging from 0.829 to 0.941 representing good to excellent repeatability (Table 2). SEM values were also relatively low, ranging from 0.6^{o} for frontal plane pelvis angle and 2.6^{o} for frontal plane rearfoot angle. ICC values ranged from 0.633 to 0.77 for transverse plane kinematics of the hip and knee representing moderate repeatability. Transverse plane trunk and pelvis kinematics demonstrated good repeatability with ICC values of 0.882 and 0.896 respectively.

3.2. Peak Angles

Several peak angles at mid stance demonstrated excellent between-day repeatability with low SEM values (Table 3). Specifically, peak trunk ipsilateral flexion, anterior pelvic tilt, contralateral pelvic drop, ipsilateral pelvis rotation, hip adduction, and ankle dorsiflexion all demonstrated excellent repeatability with ICC values greater than 0.9 and SEMs ranging from 0.6^{o} to 1.1^{o}. In the transverse plane, the hip and knee demonstrated moderate to good repeatability with ICC values of 0.739 for peak knee external rotation and 0.783 for peak hip internal rotation. Although peak hip internal rotation angle demonstrated good between-day repeatability, the largest SEM and MDC were observed for this parameter, with an SEM of 3.2^{o} and MDC of 8.7^{o}.

3.3. Excursions

ICC values for joint excursions demonstrated good to excellent repeatability for most parameters (Table 4). Hip flexion and transverse plane knee excursion demonstrated moderate repeatability with ICCs of 0.714 and 0.795 respectively. Trunk forward lean and knee adduction demonstrated poor repeatability with ICCs of less than 0.5 (Table 4). Frontal plane pelvis excursion demonstrated the lowest SEM and MDC of 0.6^{o} and 1.6^{o} while trunk forward lean demonstrated the highest SEM of 3.7^{o} and MDC of 10.4^{o}.

3.4. Toe Off

At toe off, sagittal plane lower limb kinematics demonstrated lower repeatability than the frontal and transverse planes. The lowest ICCs were observed for sagittal plane hip and knee angles with values of 0.368 and 0.109 respectively (Table 5). Conversely, at the trunk and pelvis, sagittal plane angles demonstrated good repeatability while the frontal and transverse plane demonstrated poor to moderate repeatability. SEMs and MDCs were generally large for all parameters at toe off (Table 5), with contralateral pelvic elevation demonstrating the lowest values of 0.8^{o} and 2.3^{o} respectively.

4. Discussion

The aim of the present study was to investigate the between-day repeatability, standard error of measurement (SEM) and minimal detectable change (MDC) of discrete kinematic parameters of the trunk, pelvis and lower limbs during treadmill running. The findings of the present study are in agreement with those of several previous over-ground running studies, in that sagittal and frontal plane kinematics tend to be more repeatable than those in the transverse plane [11-13]. Specifically, the present findings indicate good to excellent repeatability for sagittal and frontal plane kinematics at initial contact and peak angles during stance, while transverse plane kinematics, particularly that of the hip and knee, tended to demonstrate lower between-day reliability with large SEM and MDC values (Table 3).

Marker reapplication inaccuracies are considered to produce the largest source of error in between-day kinematic measurements, resulting in a subtle offset joint centre locations and altered segment orientations upon 3D reconstruction [17, 33]. In the current study we attempted to control for marker placement errors by ensuring the same experienced examiner positioned all static markers [24]. Despite this, a degree of error is still clearly evident within the current testing procedures highlighted by the observed SEMs (Table 2, 3, 4 & 5). That said, only one previous study has reported a lower SEM for peak transverse plane hip kinematics during running, reporting an SEM of 1.1^{o} [14]. However, this was following the use of a marker reapplication devise, designed to measure and record the precise location of anatomical reference markers, which was not available in the present study. Nonetheless, this highlights the need for methods of improving the accuracy of marker placement in order to produce greater between-day repeatability of kinematic measurements.

The lower repeatability of transverse plane hip and knee kinematics agrees with several previous repeatability studies [11, 12, 14]. In the present study, transverse plane kinematics of the hip and knee were found to demonstrate the lowest ICC's and greatest measurement errors of all peak angles and parameters at initial contact (Table 2 & 3). This could be explained by the effects of soft tissue artefact, as transverse plane kinematics are frequently reported to be influenced by excessive skin movement when using markers attached to the thigh and shank segments [34]. Consequently, caution should be taken when interpreting between-day differences in transverse plane hip and knee kinematics.

In contrast to transverse plane, sagittal and frontal plane kinematics appear to demonstrate good to excellent repeatability with lower measurement errors (Table 2, 3 & 4). This is an important finding considering sagittal and frontal plane kinematics are frequently associated with running injuries [2] and performance [4], and targeted through gait interventions [7, 10]. The high repeatability and low measurement errors suggests that interpretation of between-day kinematic parameters are less likely to be influenced by measurement error and may therefore be interpreted with a degree of confidence.

Despite lower repeatability of transverse plane kinematics, the observed repeatability values appear greater than several previous studies. Specifically, peak hip internal rotation and hip adduction were observed to demonstrate good and excellent repeatability, with ICCs of 0.78 and 0.94 respectively. Conversely, previous studies have reported ICCs of only 0.54 [12] and 0.6 [13] for peak hip internal rotation and 0.69 for peak hip adduction [12, 13]. Similar observations were made for several other parameters including peak rearfoot eversion and knee abduction, demonstrating good repeatability compared to only moderate reliability values reported elsewhere [12, 13].

One explanation for the greater repeatability observed in the present study, could be due to the use of treadmill testing procedures. Many prior studies have investigated repeatability of kinematics during over-ground running [11-13]. This could induce greater between-trial movement variability due to subtle variations in running speed, air resistance or targeting of force plates during over-ground running [35]. Only one previous study has reported the repeatability of kinematic testing procedures during treadmill running [14]. Although they did not report pelvis and trunk kinematics, Noehren et al [14] reported SEMs of 3.8^{o} and 0.9^{o} for peak hip internal rotation and adduction respectively. Similar to the SEMs of 3.2^{o} and 0.7^{o} reported in the current study and lower than that of several previous over-ground investigations [11-13]. Collectively, these results suggest that the between-day repeatability of kinematics may be improved during treadmill running. However, future studies should consider directly comparing the two.

It is worth noting that several parameters at toe off demonstrated poor repeatability with large SEMs and MDCs (Table 5). Specifically, sagittal plane hip and knee angles were found to demonstrate the lowest ICC values of all parameters of 0.368 and 0.109 respectively (Table 5). One possibility is that the repeatability of kinematics may have been influenced through the use of a kinematic algorithm to detect toe off. However, the kinematic algorithm has been shown to demonstrate only small offsets of approximately 2.5 milliseconds when compared to force plate measurements [29]. Additionally, sagittal plane kinematics of the trunk and pelvis as well as frontal and transverse plane kinematic of the hip and knee demonstrated good repeatability with ICCs greater than 0.75. Therefore, we feel the low repeatability of sagittal plane hip and knee angles at toe off is perhaps suggestive that these parameters may be more variable at this timepoint during treadmill running.

In contrast to previous studies, we reported the minimal detectable change (MDC) for a range of kinematic parameters. Inherent to any measurement system is a degree of error, which needs to be accounted for if appropriate interpretations of between-day differences are to be made. Unfortunately, many prior studies only report statistics such as the ICC [12, 14] and CMC [11, 15]. Although this provides an overall measure of repeatability, the values presented do not provide an estimate of the measurement precision and therefore have limited clinical utility [17]. In contrast, the MDC is thought to represent the minimal threshold beyond which measurement error is expected to occur. As such, the MDC could be considered the degree of change required to represent a true difference in between-day running kinematics. Therefore, we would suggest that the MDC values presented in the present study may provide a useful reference point to assist the interpretation of between-group and post intervention kinematic differences reported within future kinematic investigations.

It is important to note, that although the MDC may aid the interpretation of between-day kinematic differences, it does not necessarily represent the degree of change required for a clinically meaningful change. Several parameters in the present study demonstrate MDCs of less than 3^{o}. Whether such small changes in kinematics are sufficient to produce clinically meaningful changes in injured populations, or to tissue loading, remains unknown and should be the focus of future investigations.

There are limitations to the present study which should be acknowledged. Firstly, all participants were considered experienced runners, with a minimum two years running experience and an average weekly running volume of 71.7km per week (Table 1). It is possible that experienced runners may demonstrate more stable running patterns, with less movement variability, acquired through regular endurance running. This is in contrast to novice or injured runners, who may be more variable in their movement patterns. Future studies should consider investigating the repeatability of discrete kinematic parameters amongst populations including injured or novice runners.

5. Conclusion

The results from the present study highlight the between-day repeatability as well as the standard error of measurement and minimal detectable change of discrete kinematic parameters during the stance phase of running. This is the first study detailing the measurement error and MDC for discrete kinematic parameters of the trunk and pelvis during treadmill running. Considering stance phase kinematics are associated with common running injuries and the target of clinical interventions, the reported values may provide a useful reference point for the interpretation of whether between-day differences in running kinematics are representative of true intervention effects and not that expected to occur due to measurement error.

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Table 1: Participant characteristics. Mean [SD].

Sex		Age (years)	Mass (kg)	Height (cm)	BMI (kg/m^2)	Run Frequency (runs per week)	Average Weekly Run Volume (Kilometers)
Male	N = 6	34.4	59.7	169.1	20.7	6.5	71.7
Female	N = 10	(10.2)	(10.8)	(9.4)	(2.2)	(2.9)	(42.7)

Table 2: Between day repeatability of kinematic parameters at initial contact. ICC = Interclass correlation coefficient. SEM = Standard Error of Measurement, MDC = Minimal Detectable Change. Mean [SD] values represent degrees.

Initial Contact								
Parameter		**Mean (SD)**		**ICC**	**95%CI**		**SEM (°)**	**MDC (°)**
		Day 1	**Day 2**		**lower**	**upper**		
Trunk	Forward Lean	5.3 (5.7)	5.6 (4.4)	0.866	0.614	0.953	1.8	5.1
	Ipsilateral Flexion	2.9 (2.8)	2.9 (2.6)	0.910	0.739	0.969	0.8	2.2
	Ipsilateral Rotation	13.0 (5.7)	13.7 (8.9)	0.882	0.665	0.959	2.5	7.0
Pelvis	Anterior Tilt	8.1 (5.2)	8.0 (5.7)	0.928	0.791	0.975	1.5	4.0
	Contralateral Pelvic Drop	2.2 (1.4)	2.2 (1.3)	0.829	0.499	0.941	0.6	1.5
	Ipsilateral Rotation	2.2 (2.8)	2.1 (3.1)	0.896	0.700	0.964	0.9	2.6
Hip	Flexion	23.5 (5.1)	23.9 (6.0)	0.941	0.832	0.979	1.3	3.7
	Adduction	5.6 (2.9)	5.9 (3.1)	0.883	0.668	0.959	1.0	2.8
	Internal Rotation	0.3 (4.3)	2.0 (6.0)	0.633	0.003	0.870	3.6	8.8
Knee	Flexion	5.5 (5.8)	7.2 (6.6)	0.839	0.555	0.943	2.5	6.9
	Adduction	0.9 (3.1)	0.9 (3.5)	0.925	0.785	0.971	0.9	2.5
	Internal rotation	5.3 (6.0)	4.7 (6.4)	0.770	0.331	0.920	2.9	8.1
Foot/ Ankle	Ankle Dorsiflexion	5.4 (8.4)	4.0 (8.7)	0.914	0.761	0.970	2.5	6.9
	Rearfoot Inversion	7.0 (6.3)	8.0 (8.2)	0.868	0.628	0.954	2.6	7.2
	External Rotation	6.7 (4.7)	4.3 (5.3)	0.669	0.120	0.881	2.9	8.1

Table 3: Between day repeatability of peak kinematic parameters. ICC = Interclass correlation coefficient. SEM = Standard Error of Measurement, MDC = Minimal Detectable Change. Mean [SD] values represent degrees.

Peak Angles								
Parameter		Mean (SD)		ICC	95%CI		SEM (°)	MDC (°)
		Day 1	Day 2		lower	upper		
Trunk	Forward Lean	11.2 (6.3)	10.1 (5.2)	0.799	0.438	0.929	2.6	7.1
	Ipsilateral Flexion	4.5 (2.3)	4.1 (2.6)	0.914	0.761	0.97	0.7	2.0
	Ipsilateral Rotation	13.0 (5.6)	13.7 (8.9)	0.881	0.660	0.958	2.5	7.0
Pelvis	Anterior Tilt	6.2 (4.7)	6.1 (5.1)	0.946	0.846	0.981	1.1	3.1
	Contralateral Pelvic Drop	4.7 (2.4)	4.9 (1.8)	0.917	0.767	0.971	0.6	1.7
	Ipsilateral Rotation	5.6 (3.2)	5.4 (3.7)	0.928	0.796	0.975	0.9	2.5
Hip	Flexion	23.6 (5.1)	24.3 (6.2)	0.943	0.842	0.980	1.3	3.7
	Adduction	11.6 (2.8)	11.9 (2.7)	0.941	0.836	0.979	0.7	1.8
	Internal Rotation	3.3 (5.9)	5.8 (7.5)	0.783	0.399	0.923	3.2	8.7
Knee	Flexion	31.4 (3.5)	31.5 (5.1)	0.825	0.489	0.939	1.8	5.0
	Abduction	1.3 (2.9)	1.9 (3.4)	0.826	0.516	0.938	1.3	3.6
	External rotation	6.2 (5.0)	7.9 (6.8)	0.739	0.281	0.907	3.0	8.4
Foot/ Ankle	Ankle Dorsiflexion	21.1 (3.0)	21.29 (3.0)	0.938	0.825	0.978	0.7	2.0
	Rearfoot Eversion	2.7 (4.4)	3.17 (5.9)	0.804	0.433	0.932	2.3	6.3
	External Rotation	14.3 (6.1)	13.1 (5.7)	0.811	0.474	0.933	2.5	7.0

Table 4: Between day repeatability of joint excursion. ICC = Interclass correlation coefficient. SEM = Standard Error of Measurement, MDC = Minimal Detectable Change. Mean [SD] values represent degrees.

Joint Excursion								
Parameter		Mean (SD)		ICC	95%CI		SEM (º)	MDC (º)
		Day 1	Day 2		lower	upper		
Trunk	Forward Lean	5.9 (4.8)	4.4 (5.6)	0.476	-0.479	0.816	3.7	10.4
	Ipsilateral Flexion	1.6 (1.9)	1.2 (2.0)	0.900	0.720	0.965	0.6	1.7
	Rotation	26.1 (7.5)	26.7 (8.3)	0.949	0.855	0.982	1.8	4.9
Pelvis	Anterior Tilt	1.9 (2.9)	1.9 (2.9)	0.806	0.430	0.933	1.3	3.5
	Contralateral Pelvic Drop	2.5 (2.0)	2.7 (1.7)	0.901	0.718	0.965	0.6	1.6
	Rotation	3.4 (2.7)	3.2 (2.6)	0.955	0.873	0.984	0.5	1.5
Hip	Flexion	36.0 (6.1)	37.8 (5.1)	0.714	0.222	0.898	3.0	8.3
	Adduction	6.1 (2.2)	6.1 (2.2)	0.812	0.448	0.935	1.0	2.6
	Internal Rotation	3.1 (3.7)	3.8 (4.3)	0.816	0.486	0.935	1.7	4.7
Knee	Flexion	25.9 (5.1)	24.3 (6.1)	0.852	0.588	0.948	2.2	6.0
	Abduction	2.2 (1.8)	2.8 (2.5)	0.391	-0.724	0.787	1.7	4.8
	External Rotation	11.5 (4.6)	12.6 (3.8)	0.795	0.433	0.927	1.9	5.2
Foot/ Ankle	Ankle Dorsiflexion	15.7 (6.3)	17.3 (7.6)	0.847	0.577	0.946	2.7	7.5
	Rearfoot Eversion	9.7 (3.2)	11.1 (3.4)	0.872	0.497	0.960	1.2	3.3
	Rotation	7.7 (3.8)	8.8 (3.5)	0.903	0.669	0.968	1.1	3.1

Table 5: Between day repeatability of kinematic parameters at Toe off. ICC = Interclass correlation coefficient. SEM = Standard Error of Measurement, MDC = Minimal Detectable Change. Mean [SD] values represent degrees. – value indicates ankle plantarflexion and for pelvis, rotation away from the stance limb.

Toe Off								
Parameter		**Mean (SD)**		**ICC**	**95%CI**		**SEM (°)**	**MDC (°)**
		Day 1	**Day 2**		**lower**	**upper**		
Trunk	Forward Lean	5.8 (5.7)	5.1 (4.3)	0.873	0.642	0.955	1.8	4.9
	Ipsilateral Flexion	2.5 (1.4)	1.7 (1.3)	0.554	-0.123	0.836	0.9	2.5
	Contralateral Rotation	13.2 (4.6)	13.0 (3.5)	0.379	-0.919	0.789	3.2	8.8
Pelvis	Anterior Tilt	8.8 (3.8)	8.6 (4.3)	0.881	0.655	0.958	1.4	3.9
	Contralateral Pelvic Elevation	3.6 (1.5)	4.1 (1.7)	0.741	0.286	0.908	0.8	2.3
	Ipsilateral Rotation	-0.6 (2.4)	-0.1 (2.6)	0.811	0.474	0.933	1.1	3.0
Hip	Flexion	12.5 (5.9)	13.9 (4.1)	0.368	-0.812	0.779	4.0	11.1
	Adduction	0.3 (2.8)	-0.1 (2.2)	0.776	0.359	0.922	1.2	3.3
	Internal Rotation	0.5 (7.5)	1.9 (9.5)	0.862	0.613	0.951	3.1	8.7
Knee	Flexion	10.9 (5.3)	9.8 (4.4)	0.109	-1.698	0.695	4.6	12.7
	Adduction	0.9 (3.0)	0.2 (3.4)	0.900	0.718	0.965	1.0	2.8
	Internal Rotation	6.1 (7.5)	6.3 (7.1)	0.750	0.261	0.913	3.6	9.9
Foot/ Ankle	Ankle Dorsiflexion	-8.3 (10.9)	-11.6 (7.9)	0.646	0.044	0.874	5.7	15.7
	Rearfoot Eversion	5.7 (6.1)	5.7 (6.0)	0.715	0.155	0.902	3.2	8.8
	External Rotation	4.4 (5.7)	2.4 (5.8)	0.775	0.379	0.920	2.7	7.5