Journal of Visualized Experiments

Lower-Limb Biomechanical Characteristics Associated with Unplanned Gait Termination Under Different Walking Speeds

--Manuscript Draft--

Article Type:	Invited Methods Collection - JoVE Produced Video
Manuscript Number:	JoVE61558R2
Full Title:	Lower-Limb Biomechanical Characteristics Associated with Unplanned Gait Termination Under Different Walking Speeds
Keywords:	Unplanned gait termination; gait speed; kinetics; Kinematics; injuries; plantar pressure
Corresponding Author:	Yaodong Gu Ningbo University Ningbo, Zhejiang CHINA
Corresponding Author's Institution:	Ningbo University
Corresponding Author E-Mail:	guyaodong@nbu.edu.cn
Order of Authors:	Huiyu Zhou
	xuanzhen cen
	Yang Song
	Ukadike C. Ugbolue
	Yaodong Gu
Additional Information:	
Question	**Response**
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1 Alewife Center Suite 200 Cambridge MA 02140

TITLE:

Lower-Limb Biomechanical Characteristics Associated with Unplanned Gait Termination Under Different Walking Speeds

AUTHORS AND AFFILIATIONS:

Huiyu Zhou[1,2], Xuanzhen Cen[1], Yang Song[3], Ukadike C. Ugbolue[2], Yaodong Gu[1*]

[1]Faculty of Sports Science, Ningbo University, China
[2]School of Health and Life Sciences, University of the West of Scotland, UK
[3]Faculty of Engineering, University of Szeged, Hungary

Corresponding author:
Yaodong Gu (guyaodong@hotmail.com)

Email Addresses of Co-Authors:
Huiyu Zhou (zhouhuiyunb@qq.com)
Xuanzhen Cen (cenxuanzhen@outlook.com)
Yang Song (nbusongyang@hotmail.com)
Ukadike C. Ugbolue (u.ugbolue@uws.ac.uk)

KEYWORDS:

unplanned gait termination, gait speed, kinetics, kinematics, injuries, plantar pressure

SUMMARY:

This study compared the biomechanical characteristics of the lower extremity during unplanned gait termination under different walking speeds. The lower-limb kinematic and kinetic data from fifteen subjects with normal and fast walking speeds were collected using a motion analysis system and plantar pressure platform.

ABSTRACT:

Gait termination caused by unexpected stimulus is a common occurrence in everyday life. This study presents a protocol to investigate the lower-limb biomechanical changes that occur during unplanned gait termination (UGT) under different walking speeds. Fifteen male participants were asked to perform UGT on a walkway at normal walking speed (NWS) and fast walking speed (FWS), respectively. A motion analysis system and plantar pressure platform were applied to collect lower-limb kinematic and plantar pressure data. Paired-sampled T-test was used to examine the differences in lower-limb kinematics and plantar pressure data between two walking speeds. The results showed larger range of motion in the hip, knee, and ankle joints in the sagittal plane as well as plantar pressure in forefoot and heel regions during UGT at FWS when compared with NWS. With the increase in walking speed, subjects exhibited different lower-limb biomechanical characteristics that show FWS associated with greater potential injury risks.

INTRODUCTION:

Human locomotion is considered to be an extremely complex process that needs to be described by multidisciplinary methods[1,2]. The most representative aspect is the gait analysis by biomechanical approaches. Human gait aims to sustain progression from initiation to termination, and the dynamic balance should be maintained in position movement. Although gait termination (GT) has been extensively studied as a sub-task of gait, it has received less attention. Sparrow and Tirosh[3] defined GT in their review as motor control period when both feet stop moving either forward or backward based on the displacement and time characteristics. Compared to steady-state gait, the process of executing GT demands higher control of postural stability and complex integration and cooperation of the neuromuscular system[4]. During GT, the body needs to rapidly increase the braking impulse and decrease propulsion impulse to form a new body balance[5,6]. Unplanned gait termination (UGT) is a stress response to an unknown stimulus[6]. When confronted by an unexpected stimulus that requires one to stop suddenly, initial dynamic balance will be disrupted. Because of the need for the continuous control of the body's center of mass (COM) and feedback control, UGT poses a greater challenge to postural control and stablity[3,7].

UGT has been reported to be an important factor leading to falls and injuries, especially in elderly people and patients with balance disorders[3,8]. Faster walking speeds may lead to an additional decline in motor control during UGT[9]. Ridge et al.[10] investigated the peak joint angle and internal joint moment data of children during UGT at normal walking speed (NWS) and fast walking speed (FWS). The results showed larger knee flexion angles and extension moments at faster speeds compared with preferred speed. They indicated that strengthening the related muscles surrounding the lower extremity joints could be a useful intervention for injury prevention during UGT.

Although the effect of walking speed on the lower-limb biomechanical character during steady-state gait has been extensively studied[11-13], the biomechanical mechanism of UGT under different walking speeds is limited. To our knowledge, only three studies have specifically evaluated healthy individuals' UGT performances with respect to velocity effects[9,10,14]. However, subjects in these studies were mainly the elderly[14] and children[10], the biomechanical mechanism of young adults during UGT is still unclear. Lower-limb kinematics and plantar pressure can provide a precise analysis of locomotion biomechanics, and these are also considered to be crucial components for clinical gait diagnoses[15,16]. For example, Serrao et al.[17] used lower-limb kinematic data to detect the clinical differences between patients with cerebellar ataxia and healthy counterparts during sudden stopping. Besides, compared to planned gait termination (PGT), larger peak pressure and force in the lateral metatarsal during UGT could be observed[7], which may be associated with higher injury risks.

Therefore, exploring the biomechanical mechanisms of UGT could provide insights for injury prevention and further clinical researches. This study presents a protocol to investigate any biomechanical alteration in young adults during UGT under different walking speeds. It is hypothesized that, with an increase in walking speed, participants would exhibit different lower-limb biomechanical characteristics during UGT.

PROTOCOL:

The Human Ethics Committee of Ningbo University approved this experiment. All written informed consent was obtained from all subjects after they were told about the goal, requirements, and experimental procedures of the UGT experiment.

1. Laboratory preparation for gait

1.1 Kinematics: Motion capture system

1.1.1 When calibrating the system, turn off the incandescent lights and remove any possible reflective objects that can be mistaken for passive retro-reflective markers. Ensure that eight infrared cameras are properly aimed and have a clear and reasonable view.

1.1.2 Plug the appropriate USB dongle into the PC's parallel port. Switch on the motion-capture infrared cameras and analog-to-digital converter.

1.1.3 Open the tracking software in the PC and allow time for the eight infrared cameras to initialize. Select "**Local System**" node of the "**Resources**" pane. Every camera node will show a green light if the hardware connection is true.

1.1.4. Adjust the system parameters in the Camera view pane: set the Strobe Intensity to 0.95 - 1, Threshold to 0.2 - 0.4, Gain to times 1 (x1), Grayscale Mode to Auto, Minimum Circularity Ratio to 0.5, and Max Blob Height to 50.

1.1.4 Put the T-frame consisting of 5 markers in the center of the motion capture area. Select all cameras using 2D mode and confirm that they can view the calibration wand (T-frame) without any interference and/or artefacts. Click the "**System Preparation**" item in the toolbar and select the **5 marker Wand & T-Frame calibration object** from the **T-Frame drop-down list**.

1.1.5 In the "**Tool**" pane, select the "**System Preparation**" button, and click the "**Start**" button in the "**Calibrate Cameras**" section. Then physically wave the T-frame in the capture range. Stop the action when the blue lights on the infrared cameras stop flashing. Monitor the progress bar until the Calibration Process is completed at "**100%**"and returns to "**0%**".

NOTE: Ensure the values of the **Image Error** are less than 0.3.

1.1.6 Put the T-frame on the floor (the center of the motion capture area) and ensure the axes of T-frame are consistent with the heading direction.

1.1.7 Select the "**Start**" button under the "**Set Volume Origin**" section in the Tool pane.

1.2 Plantar pressure: Pressure platform

1.2.1 Put the 2 m pressure platform in the center of the test area. Notice the eight infrared

cameras displayed around the pressure platform.

1.2.2 Divide the pressure platform into four average areas, A, B, C and D (each area is 50 cm * 50 cm) in a linear fashion and distinguish them with an alphabet label / sticker **(Figure 1)**.

1.2.3 Keep the PC and pressure platform connected via the proprietary data cable.

1.2.4 Double-click the software icon on the desktop.

1.2.5 Click the "**Weight Calibration**" on the Calibration Screen and input the body mass of a staff. Ask him or her to stand on the pressure platform, waiting until the system completes the calibration automatically before he/she can leave the pressure platform.

[insert **Figure 1** here]

2. Participant preparation

2.1 Before the UGT test, interview all subjects and provide them with a simple explanation about the experimental goals and procedures. Obtain written informed consent from subjects who meet the key inclusion criteria.

2.1.1. Include participants who are physically active male adults, have the right leg as dominant, do not have any hearing disorder, do not have lower-limb disorders, and have not incurred injuries in the last six months.

NOTE: 15 male subjects (age: 24.1 ± 0.8 years; height: 175.7 ± 2.8 cm; body weight: 68.3 ± 3.3 kg; foot length: 252.7 ± 2.1 mm) who met the experimental conditions were included in this test.

2.2 Allow all subjects fill in a questionnaire survey.

NOTE: Questions include: Have you had a history of running or other physical activities? How often do you do physical activities in a week? Do you have any professional athletic training? Have you suffered any lower-limb disorders and injuries in the last six months?

2.3 Ensure that all subjects wear identical t-shirts and tight-fitting pants.

2.4 Measure subjects' standing height (mm) and body weight (kg), lower limb length (mm), knee width (mm) and ankle width (mm) of both left and right leg using Vernier caliper or small anthropometer.

NOTE: Measure the lower limb length from the superior iliac spine to the ankle medial condyle; the knee width from the lateral to the medial knee condyle; the ankle width from the lateral to the medial ankle condyle.

2.5 Shave off the body hair as appropriate and remove excess sweat using alcohol wipes. Prepare skin areas of anatomical bony landmarks for marker placement on joints and segments.

NOTE: This study used 16 reflective markers[18], including anterior-superior iliac spine (LASI/RASI), posterior-superior iliac spine (LPSI/RPSI), lateral mid-thigh (LTHI/RTHI), lateral knee (LKNE/RKNE), lateral mid-shank (LTIB/RTIB), lateral malleolus (LANK/RANK), second metatarsal head (LTOE/RTOE) and calcaneus (LHEE/RHEE) **(Figure 2)**.

2.6 Identify 16 anatomical landmarks. On the landmarks, attach passive retro-reflective markers with double-sided adhesive tapes.

2.7 Give each subject 5 min to adapt to the test environment and warm up with light running and stretching.

[insert **Figure 2** here]

3. Static calibration

3.1 Kinematics: Motion capture system

3.1.1 In the tracking software, find the "**New Database**" in the toolbar to build a database. Click the "**Data Management**" to open the "**Data Management**" pane and click in order the "**New Patient Classification**", "**New Patient**" and "**New Session**" button. Return to the "**Resources**" window, select "**Create A New Subject**" button to create a subject, and enter the values of height (mm), body weight (kg), leg length (mm), knee width (mm), and ankle width (mm) in the "**Properties**" pane.

3.1.2 Click the "**Go Live**" and then click the "**Split Horizontally**" in the "**View**" pane. Then select the graph to view the Trajectory count.

NOTE: Check the "**3D Perspective**" pane to ensure that all 16 markers are visible.

3.1.3 Ask subjects to stand still in the area A. Click "**Start**" in the subject capture section to capture the static model. About 200 frames of images were captured before clicking the "**Stop**" button.

3.1.4 In the "**Tools**" pane, find the "**Pipeline**" button, and click on "**Run the reconstruct pipeline**" to build a new 3D image of all captured markers. Identify in the markers' list, and manually apply the corresponding labels to the markers. Save and press "**ESC**" key to exit.

3.1.5 Select "**Subject Preparation**" and "**Subject Calibration**" in the toolbar and choose the "**Static plug-in gait**" option in the drop-down menu.

3.1.6 Select the "**Left Foot**" and "**Right Foot**" in the "**Static Settings**" pane and click the "**Start**". Then save the static model.

3.2 Plantar pressure: Pressure platform

3.2.1 In the software, click "**Database**" to add a new patient. And enter the assigned subject number in the "**Add Patient**" pane. Then, click "**Add**".

3.2.2 Click "**Dynamic**" and enter body weight and shoe size. Then, click "**OK**".

4. Dynamic trials

4.1 Ask the subject to be at the starting position.

4.2 Software Operations

NOTE: The two kinds of software start (Motion capture system: click "**Capture**" button; Pressure platform: click "**Capture**" button) and end (Motion capture system: click "**Stop**" button; Pressure platform: click "**Save Measurement**" button), simultaneously.

4.2.1 Kinematics: Motion capture system

4.2.1.1 Select the "**Go Live**" button in the "**Resources**" pane and click "**Capture**" in the right toolbar. Find "**Trial Type**" and "**Session**" from top to bottom and edit "Trial" description.

4.2.1.2 Ask subjects to perform UGT test as described in 4.3.

4.2.1.3 After finishing the UGT test, click "**Stop**" to end the data collection trial. Repeat the above steps for 5 times.

4.2.2 Plantar pressure: Pressure platform

4.2.2.1 Select the "**Measure**" button before starting the UGT trials.

4.2.2.2 After finishing the UGT test, click "**Save Measurement**" button to save data. Repeat the above steps for 5 times.

4.3 UGT trials

4.3.1 Ask subjects to walk along a walkway at their NWS and instruct them to use the dominant leg and non-dominant leg to pass area A and B, respectively, and finally stop at area D on the pressure platform.

4.3.2. Let the subject know when the termination signal is provided they need to quickly stop

on area B.

4.3.3. Randomly provide the termination signal as the heel touches area A, ensure that the UGT is executed and subjects stop quickly on area B **(Figure 1)**. The staff sends the termination signal by randomly ringing a red bell, and the probability of ringing was controlled at about 20%. Capture at least five successive UGT trials.

NOTE: There is a 2-min rest interval between both trials.

4.3.4 Calculate each subject's walking speed using the pressure platform software. Then, calculate the FWS as 125% of the NWS.

4.3.5. Repeat the above UGT test for the FWS. Capture at least 5 successive UGT trials using the FWS protocol.

5. Post-processing

5.1 Kinematics: Motion capture system

5.1.1 Find the "**Data Management**" button in the toolbar and double-click the trial name in the "**Data Management**" pane. Then select "**Reconstruct**" and "**Label**" to reconstruct the 3D dynamic model.

5.1.2 On the "**Time**" bar, move the blue triangles to set the required range of time (for the stance phase during UGT).

5.1.3 Click on the "**Time**" bar. Then click "**Zoom to Region-of-Interest**" in the "**Context**" menu.

5.1.4 Click the "**Label**" button to identify and check the label points. Ensure the steps are the same as the static identification process.

NOTE: Fill in some incomplete identification markers and delete the unlabeled markers (if necessary).

5.1.5 Choose the "**Dynamic Plug-in Gait**" in the "**Subject Calibration**" pane. Then click the "**Start**" button to run the data. Export dynamic trials in ".csv" format for following data analysis.

5.1.6 Use a fourth-order low pass Butterworth filter with cut off frequency of 10 Hz and export the data of the joint angle.

5.1.7 Calculate the range of motion (ROM) of three joints (hip, knee, and ankle) in sagittal plane.

NOTE: Define the differences between the maximum angles and minimum angles of the hip, knee, and ankle on the sagittal movement planes as the ROMs.

5.1.8 Calculate means (M) and standard deviations (SD) of the ten trials (5 for NWS, and 5 for FWS) from each subject.

5.2 Plantar pressure: Pressure platform

5.2.1 Select the trial name from the "**Measurements**" menu of the corresponding subjects. Click the "**Dynamic**" button to open data.

5.2.2 Click the "**Manual**" selection. Use the "**Left Mouse**" button to select the step of interest (the stance phase during GT). Click the "**OK**" button to save.

5.2.3 Click the "**Zone Division**" and "**Manual Zone Selection**" to make adjusts. Then click the "**Accept**" button to save.

5.2.4 Open "**Pressures-Forces**" screen and click the "**Graph Composition**" button to open the "**Zone Graph Composition**" window. Divide 10 anatomical regions, including Big Toe (BT), Other Toes (OT), First Metatarsal (M1), Second Metatarsals (M2), Third Metatarsal (M3), Fourth Metatarsal (M4), Fifth Metatarsal (M5), Mid-Foot (MF), Medial Heel (MH) and Lateral Heel (LH). Then click the "**OK**" button to save.

5.2.5 Click "**Parameter Table**" to export plantar pressure data, including maximum pressure, maximum force and contact area.

5.2.6 Calculate Means and SDs for 10 trials (5 for NWS, and 5 for FWS) from each subject.

6. Statistical analysis

6.1. Perform the Shapiro–Wilks tests to check normal distribution for all variables. Use Paired-sampled T-tests to compare lower limb kinematics and plantar pressure data during UGT at NWS and FWS. Set the significance level at $p < 0.05$.

REPRESENTATIVE RESULTS:

Mean & SD values of NWS and FWS of 15 subjects were 1.33 ± 0.07m/s and 1.62 ± 0.11m/s, respectively.

Figure 3 shows the mean ROM of the hip, knee, and ankle joints in the sagittal plane during UGT at NWS and FWS. Compared with NWS, the ROM of three joints increased significantly at FWS ($p<0.05$). In detail, the ROM of hip, knee and ankle joints increased from 22.26 ± 3.03, 29.72 ± 5.14 and 24.92 ± 4.17 to 25.98 ± 2.94, 31.61 ± 4.34 and 28.05 ± 5.59, respectively **(Figure 3)**.

[insert **Figure 3** here]

Figure 4 shows the plantar pressure data including maximum pressure **(Figure 4A)**, maximum force **(Figure 4B)** and contact area **(Figure 4C)** during UGT at NWS and FWS. Compared with NWS, the maximum pressure in BT, M1, M2, M3, MH and LH increased significantly during UGT at FWS ($p<0.05$). Similarly, for maximum force, significant increase was observed in BT, M1, M2, M3, MH and LH at FWS compared to NWS ($p<0.05$). However, no significant difference occurred in any parameters for the OT, M4, M5 and MF regions ($p>0.05$). Differences in contact area mainly focused on the heel region, i.e., MH and LH, and both increased greatly at FWS when compared to NWS ($p<0.05$).

[insert **Figure 4** here]

FIGURE AND TABLE LEGENDS:

Figure 1: Experimental protocol. If subjects received the termination signal as the heel touched area (**A**), the UGT was executed so that the subject stopped in area (**B**). Kinematic and plantar pressure data were collected synchronically.

Figure 2: The reflective markers attached to the lower limbs. (**A**) side, (**B**) front and (**C**) rear.

Figure 3: The ROMs of three joints in the sagittal plane during UGT at different speeds. The error bars indicate standard deviation. * indicates the significance level ($p<0.05$).

Figure 4: Plantar pressure data. This includes maximum pressure (**A**), maximum force (**B**), and contact area (**C**) during UGT at different speeds. The error bars indicate standard deviation. * indicates the significance level ($p<0.05$).

DISCUSSION:

Most previous studies that analyze gait biomechanics during UGT omit the importance of walking speed in their biomechanical assessment. Thus, this study investigated the lower-limb biomechanical changes that occur in UGT at NWS and FWS with the aim to reveal the speed-related effects.

Significant differences have been found on the ROM of the hip, knee, and ankle joints in the sagittal plane during UGT at NWS and FWS. Our findings showed greater ROMs of the 3 joints in the sagittal plane during UGT at FWS compared with NWS. These results were nearly consistent with previous study in regard to the effect of speeds during walking[19]. Ridge et al.[10] found that larger peak flexion angles in knee and hip joint during UGT at FWS than NWS. Larger sagittal knee ROM may be a compensatory movement due to the increased gait speed[20], resulting from greater knee impact during UGT. Subjects stabilized with larger range of hip, knee, and ankle joints motion, which may contribute to faster terminating times, but may also need greater joint extensor activity for stability[21].

It must be mentioned as well, plantar pressure data including maximum pressure, maximum force and contact area increased in all anatomical regions during UGT at FWS compared with NWS. For maximum pressure and force, the significant differences mainly focused on medial

forefoot and heel, which is consistent with the previous study[22]. In this study, although the plantar pressure in the lateral metatarsals also increased, there was no significant difference between speeds. The imbalance between the medial-lateral plantar pressure may lead to a decrease in medial-lateral stability during UGT[7]. Excessive peak pressures in heel may increase the risk of foot injuries, such as stress fractures[23,24]. Moreover, the significant increased contact areas were exhibited in MH and LH, which may be related to the calcaneus that contact initially with the ground after the terminal swing phase and most of the body mass is loaded during this phase[25].

The results are counted on several key steps in the protocol. First, identify anatomical landmarks and accurately attach the markers to the subjects' skin. Ensure the markers are securely placed on the skin with hypoallergenic double-sided adhesive tape to reduce the likelihood of the marker dropping or shifting. Second, it is vital to send the terminated signal to subjects in the fixed phase. In order to reduce the error, the signal sent in all trials was executed by the same staff. Third, ensure that the artificial division of plantar the anatomical regions are accurate. Besides, there are certain limitations associated with the present study which should also be noted. First, no female subject participated in the study, which was originally for the purpose of controlling variables. Second, lower-limb muscle activities were not collected in the study. Muscle activation count a lot in explicating lower-limb biomechanical character during UGT[9,14], and we are willing to investigate the effect of walking speed on lower-limb muscle activities in the future study for additional insights into biomechanical mechanism during UGT.

The results of the present study suggest that as increments in walking speeds occur subjects exhibit different lower-limb biomechanical characteristics during UGT. This outcome may be an indication that an increase in walking speeds, particularly at FWS may bring about greater risk of potential injuries. Furthermore, considering previously explored relationships between plantar pressure, kinematics of lower limb joints, and sports injuries, the results of this study suggest that gait termination trials at different speeds could be used as an effective tool for diagnosis of clinical biomechanical performance and assessment of rehabilitation treatment.

ACKNOWLEDGMENTS:

NSFC-RSE Joint Project (81911530253), National Key R&D Program of China (2018YFF0300905), and K. C. Wong Magna Fund in Ningbo University.

DISCLOSURES:

No potential conflict of interest was reported by the authors.

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Figure 1

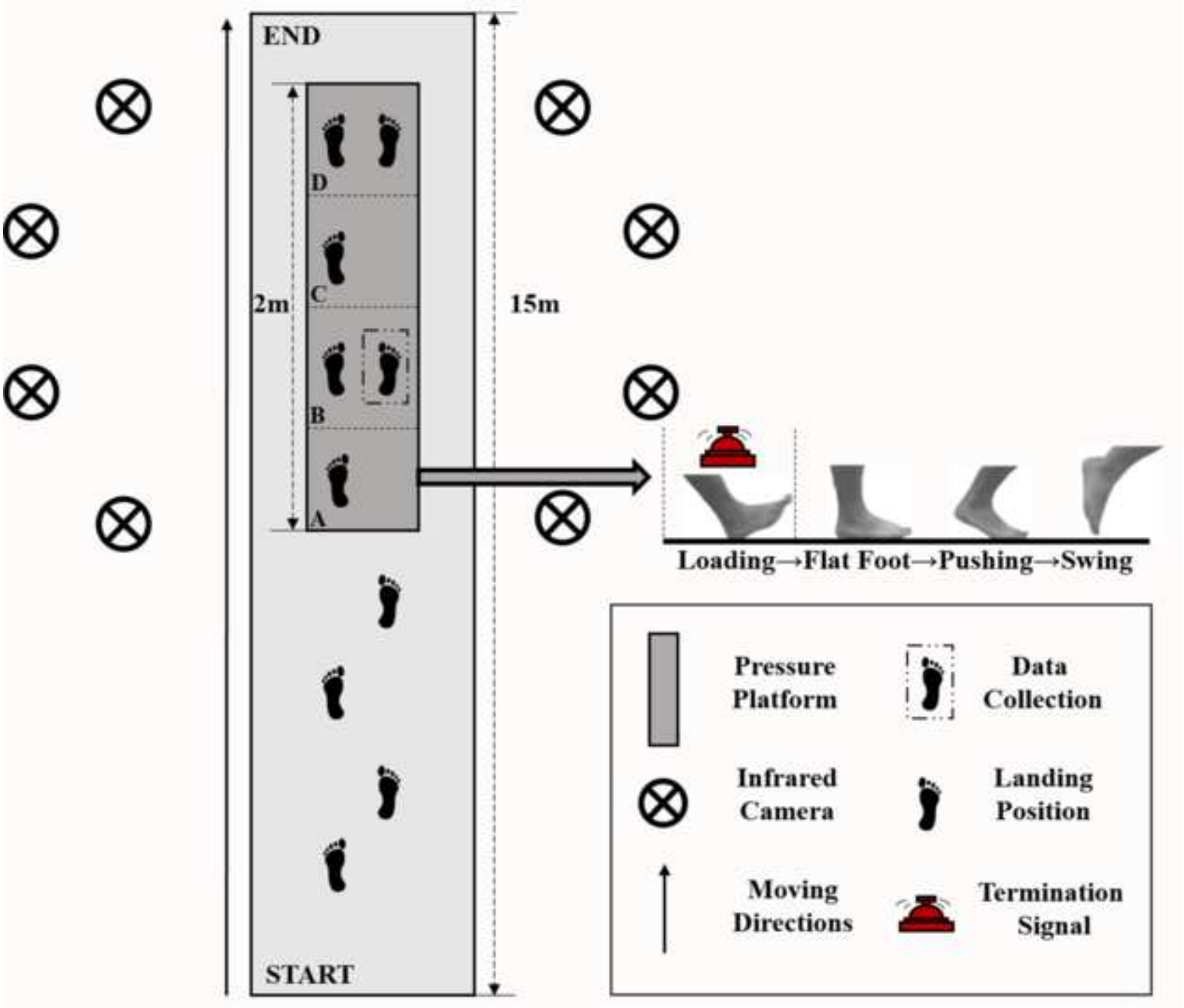


Figure 2

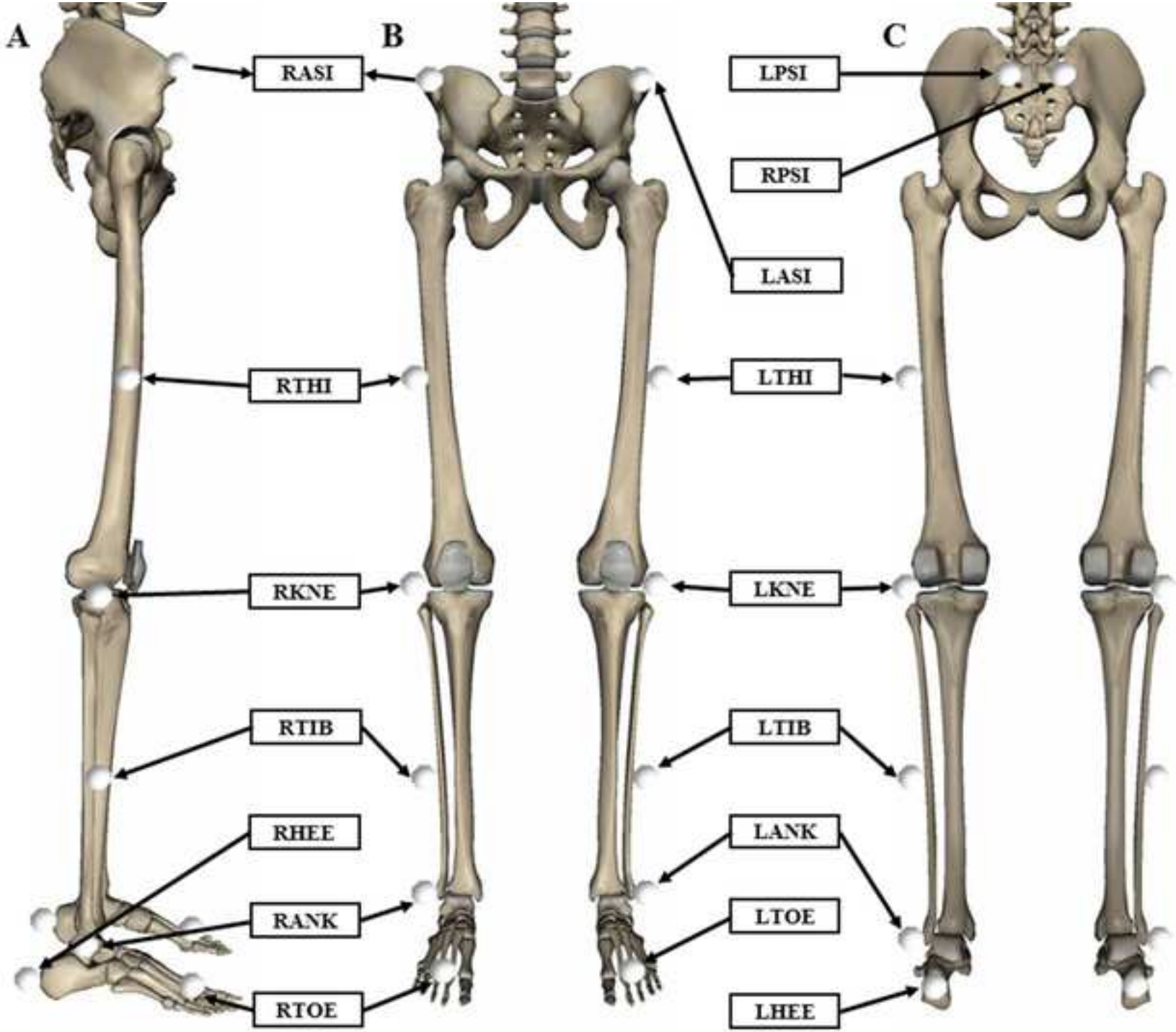


Figure 3

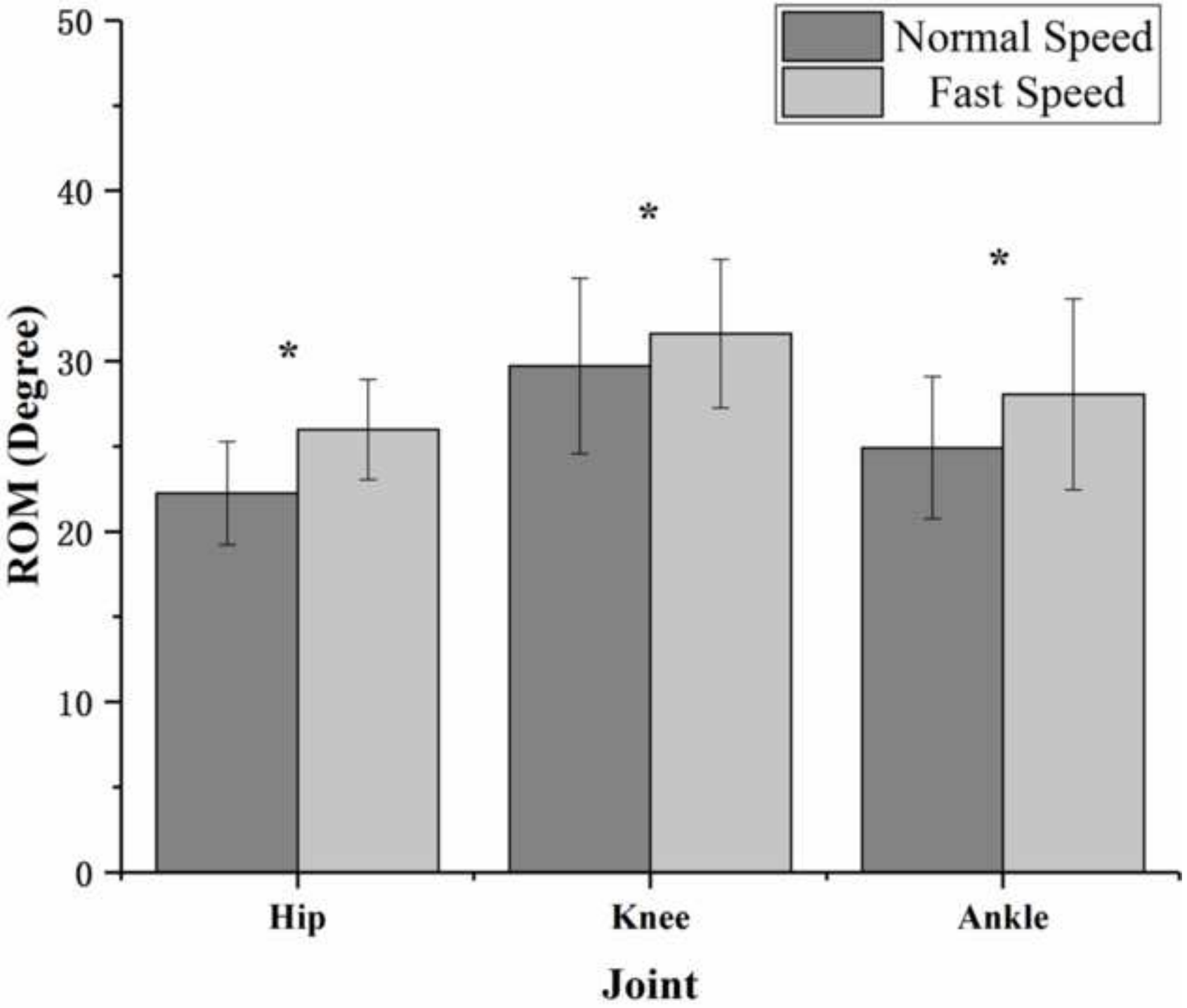
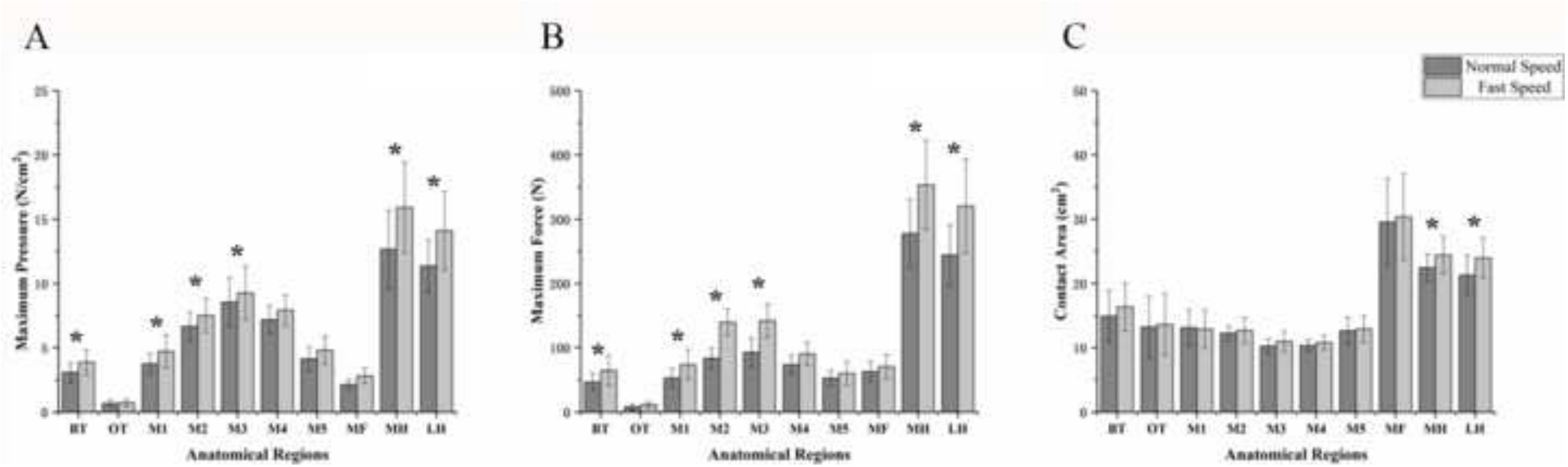


Figure 4

Click here to access/download;Figure;Figure 4.tif



Name of Material/ Equipment	Company	Comments/Description
14 mm Diameter Passive Retro-reflective Marker	Oxford Metrics Ltd., Oxford, UK	n=22
Double Adhesive Tape	Oxford Metrics	For fixing markers to skin
Heart Rate	Garmin, HRM3-SS, China	Detection of fatigue state
Motion Tracking Cameras	Ltd., Oxford, UK	n= 8
T-Frame	Ltd., Oxford, UK	-
Treadmill	Smart Run,China	the process.
Valid Dongle	Ltd., Oxford, UK	Vicon Nexus 1.4.116
Vicon Datastation ADC	Ltd., Oxford, UK	-

Authors' response to Editor

Dear Editor,

Thank you very much for inviting us to submit a revised version of the manuscript. We have attached all of the editorial comments below followed by our point-by-point responses. Revised portion are highlighted in red in the paper. We hope the manuscript is now suitable for publication and look forward to your reply.

Editorial comments and responses

1. The editor has formatted the manuscript to match the journal's style. Please retain and use the attached file for revision.

***Answer**: Thank you very much. We have used the attached file for revision.*

2. Please address all the specific comments marked in the manuscript.

***Answer**: Thanks. We have addressed all the specific comments marked in the manuscript and followed by our point-by-point responses.*

1) Since one of your authors is from UK please pick, I agree to UK ALA in the editorial manager when submitting the manuscript. Also please ensure that you are allowed to publish standard access article.

***Answer**: The UK authors are allowed to publish standard access.*

2) Please include at least 6 keywords or phrases.

***Answer**: We have added a keyword.*

3) The time, the gait, motor control period - something seem to missing here.

***Answer**: Thanks. We have made the revisions in the manuscript.*

4) With respect to instead of regarding?

***Answer**: Thank you for the suggestion, we have replaced "regarding" by "with respect to" in the manuscript.*

5) On what criteria? Rationale for doing this?

***Answer**: The size of the four areas A, B, C and D was set according to the area of the Footscan pressure plate (each area was about 50cm*50cm). The purpose of the four areas settings is to make the subjects and readers better understand the experimental methods of this study. Therefore, their area is not fixed in the actual experiment, that is, each step of the subject is not. This procedure followed a previously established protocol.*

References: Cen, X., Jiang, X. & Gu, Y. Do different muscle strength levels affect stability during unplanned gait termination? Acta of bioengineering and

biomechanics. 21 (4), 27-35, (2019).

Cen, X., Xu, D., Baker, J. S. & Gu, Y. Effect of additional body weight on arch index and dynamic plantar pressure distribution during walking and gait termination. PeerJ. 8 e8998, (2020).

Cen, X., Xu, D., Baker, J. S. & Gu, Y. Association of Arch Stiffness with Plantar Impulse Distribution during Walking, Running, and Gait Termination. International Journal of Environmental Research and Public Health. 17 (6), 2090, (2020).

6) Which button is clicked?

***Answer**: Thanks. We have made the revisions in the manuscript.*

7) What are these values used for?

***Answer**: These values are the information that must be entered when subjects are created in the Tracking Software of Motion Capture System.*

8) Citation for these markers. Why only these markers?

***Answer**: Optical tracking systems, currently used in the majority of gait-analysis laboratories for both clinical and research purposes, give accurate and reliable measurement of 3D lower-limb joint motions. This technology provides a "gold standard" for gait analysis. The standard PLUG IN GAIT model was used for the study.*

References: Zhang, Y., Wang, M., Awrejcewicz, J., Fekete, G., Ren, F., Gu, Y. Using Gold-standard Gait Analysis Methods to Assess Experience Effects on Lower-limb Mechanics During Moderate High-heeled Jogging and Running. J. Vis. Exp. (127), e55714.

9) So these buttons appears one after another in the data management pane?

***Answer**: These buttons are in the same window and are arranged in order.*

10) Where is the capture area- A, B C, D?

***Answer**: Thanks. We have made the revisions in the manuscript.*

11) How is this done? Please

***Answer**: We described UGT Trials in 4.3.*

12) In your case, how many times did you repeat the test? What is the max and min time this can be repeated?

***Answer**: Thanks. We have made the revisions in the manuscript.*

13) So only the markers are used to determine the plantar pressure? Is there a specific walking mat associated with the software to determine plantar pressure?

***Answer**: Pressure platform was used to collect the Plantar Pressure of the subjects.*

The markers were used to collect kinematic data of joints through the motion capture system.

14) When is this done- before starting the UGT test? Please bring out clarity

***Answer**: Thanks. We have made the revisions in the manuscript.*

15) How many times did you repeat in your case?

***Answer**: Thanks. We have made the revisions in the manuscript.*

16) How do you determine the pressure? How do you control the speed of walking? Do you perform any trial runs before? This is for NWS?

***Answer**: Pressure platform was used to collect the Plantar Pressure of the subjects. The subjects' normal walking speed does not need to be controlled, only the most natural gait. During subject preparation, each subject was given five minutes to warm up, including walking on the walkway at a natural walking speed.*

17) How long is the trial? Is there any rest period in between?

***Answer**: Thanks. We have made the revisions in the manuscript.*

18) How?

***Answer**: After completing the gait trial, pressure Platform Software will automatically calculate the gait speed according to the subject's gait. Therefore, no additional operations are required.*

19) How do you check and normalize for normal walking speed and fast walking speed? So the test is conducted in both cases?

***Answer**: The subjects were asked to complete the test at a normal walking speed and then at a fast walking speed. The walking speed was monitored by plantar pressure software.*

20) How is this done?

***Answer**: Define the difference between the maximum angle and minimum angle of the hip, knee, and ankle on the sagittal movement planes as the ROMs.*

21) Changed to figure 3.

***Answer**: Done.*

3. Once done please ensure that the highlighted section is no more than 2.75 pages including headings and spacings.

***Answer**: Thanks. We have ensured that the highlighted section is no more than 2.75 pages including headings and spacings.*

4. When uploading the files, please select I agree to UK ALA on the additional info

page because one of your authors is from UK.

***Answer**: Thanks for the reminding. We will select I agree to UK ALA on the additional info page.*

5. Please ensure that the UK authors are allowed to publish standard access.

***Answer**: Thanks. We have ensured that the UK authors are allowed to publish standard access.*

6. Please check with your funding source regarding PMC deposition. We do not deposit articles into PubMed Central on behalf of the authors. However, authors can self-deposit into PMC if required by their funding source.

***Answer**: Thanks. We have checked with our funding source regarding PMC deposition.*