

Study of Knee Kinematics during Walking and Running in Middle-Aged Males

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ABSTRACT

This paper aimed to figure out knee altered kinematics and to investigate possibility of knee injury in middle-aged males when performing walking and running. Twelve healthy middle-aged males (45-60 years) volunteered to perform walking 3 km/h and running 5 km/h on treadmill in the biomechanics laboratory. A set of markers were attached to specify knee landmarks of each participant, who was tracked by a 7-camera 3D motion capture system. The marker positions were used to determine the segment coordinate system (SCS) for calculation of knee flexion, as well as abnormal kinematics included knee internal rotation, varus rotation and anteroposterior translation. The result showed similarity of knee altered kinematics during walking and running. The maximum of knee flexion, internal rotation and varus rotation of running were higher than walking significantly, whereas there was no significant difference in anteroposterior translation ($p < 0.05$). The repetitive anteroposterior translation could increase the risk of knee injury, while increased varus and internal rotation have been associated with the progression of iliotibial friction syndrome. This study provides the information that middle-aged males runners can use to develop running techniques.

KEYWORDS: Knee kinematics /Walking /Running /Male middle aged

INTRODUCTION

Middle aged is a crucial time to enhance physical fitness for confronting physical changes in the elderly stage of life [1]. Running is a popular alternative for leisure-time exercise and enhancing cardiovascular system [2][3]. According to marathon fever in Thailand, the participation has been particularly prevalent among middle-aged non-elite runners and most of them choose to enjoy walking and running without expecting results [6]. Despite this activity may be considered as moderate exercise, a survey study in Bangkok marathon reported that 54.1% of injury occurrence were knee and popliteal areas [7]. Unfortunately, prevalence surveys has observed osteoarthritis of the knee is common in middle aged and older adults [8].

Runners commonly face with leg pain due to bone, musculotendinous and vascular causes [5]. Previous study showed evidences of knee kinematic abnormality occurrence during or shortly after long-distance running such as increased of knee varus rotation, anterior translation and internal rotation [4]. In a retrospective study of running injury, increasing of kinematic abnormalities in mature person has previously been associated with development of overuse injuries, [9], and contribute to compartment syndrome [5]. It reasonable that the increase of abnormal knee movements have been considered cause of physical damage. Therefore, understanding of knee kinematic alterations during running are necessary to correct these condition.

Several studies reported knee kinematic alterations during walking and running which focused on effect of sex or

distance running [4 12]. A few information that specifically explain the acute effect from running. Normal knee kinematics during walking can be used as a baseline reference for difference analysis of kinematics alterations [10]. This paper aimed to figure out knee kinematic alterations and investigate possibility of knee injury in middle-age males when performing walking and running using optical motion capture system. To study guidelines for the development of running techniques.

PARTICIPANTS

Twelve male university employees who no self-reported of knee osteoarthritis volunteered to this study. The participants were between 45-60 years of ages. The characteristics of the participants were shown in Table 1. The participants had no significant history of musculoskeletal injury prior to data collection. Ethics approval was granted by the Ethics institutional review board, Thailand national sports university. Written consent was received from all participants.

Table 1. Participant characteristics (mean \pm SD).

Participant (N = 12)	mean \pm SD
Age, (year)	55 \pm 5
Body weight, (kg)	74 \pm 11.6
Height, (cm)	169 \pm 6.1
BMI	25 \pm 8.9
Q-angle, (deg)	14 \pm 2.2

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EXPERIMENTAL PROCEDURE

The participants were measured for body mass, height and were fitted with 20 reflective markers (1.6 cm diameter) to identify the following landmarks bilaterally: anterior-superior iliac spine, greater trochanter, lateral femoral epicondyle, medial femoral epicondyle, lateral tibial plateau, medial tibial plateau, tibial tuberosity, lateral tibial malleolus, medial tibial malleolus, 2nd metatarsal head.

After self-selected warm-up, the participants were asked to perform 8-10 min walk on treadmill to adapt their motion similar with ground gait. 7-camera motion capture system (Qualisys AB, Gothenburg, Sweden) with sampling at 300Hz. were used to record 3D position of markers during 15 s of walking at 3km/h and running 5km/h.

DATA ANALYSIS

The 3D position of markers were exported to analyze using customized MATLAB code (R2019a, MathWorks Inc., Natick, MA, USA) to calculate kinematics of the right knee performed by each participant under walking and running condition. The kinematics utilized a movement axis of femur SCS relative to tibia SCS. The femur and tibia SCS were established based on a previous study [12]. The Euler angle sequence X-Y-Z, representing the angle of knee flexion, varus rotation and internal rotation respectively. The anteroposterior translation was quantified as relative displacement between origins of tibia in the femur SCS. All 4 kinematics during walking and running gait cycles were normalized to 100 point (first and last point were initial ground contact, determined from a video) and low-pass filtered using a fourth order Butterworth filter with a cut-off frequency of 10Hz. Subsequently, mean curves of all kinematics were conducted to visualize the kinematic alterations (Fig.1). Maximum values of parameter, including knee flexion, varus rotation, internal rotation and anteroposterior translation of each participant was collected and compared between walking and running conditions.

Statistical analysis

Statistical comparison between walking and running was performed with paired t-tests for parametric variables and Wilcoxon signed-rank tests for non-parametric variables. The statistical analysis utilized SPSS version 22.0 (IBM, Armonk, NY, USA) and was set level of significance at $P < 0.05$, two-tailed.

RESULTS

The altered kinematic curves were similar during walking and running as shown in Fig.1. According to the results, running in every parameters showed higher angle than walking throughout the cycle. Flexion pattern demonstrated two peaks, first peak in the early stand phase at about 10% of the cycle. Another peak was maximum flexion that occurred during swing phase at about 70% of the cycle. Similarly, varus rotation reached first peak in the stance phase and another peak during swing phase. The internal rotation gradually increased since toe-off and reach maximum value at about 80% of the cycle. Using walking as a baseline for maximum kinematics comparison are shown in Table 2. Running significantly higher flexion by 14.4 (SD 4.2) $P < 0.001$ and significantly higher varus rotation and internal rotation by 2.4 (SD 3.6), $P = 0.035$, and 1.6 (SD 3.3) respectively. In terms of anteroposterior translation, the difference between walking and running was not statistically significant. It was slightly before heel-strike when the peak of tibia move anteriorly. Subsequently, it reversed direction

to gradually move posteriorly until reaching another peak during swing phase about 58.2%.

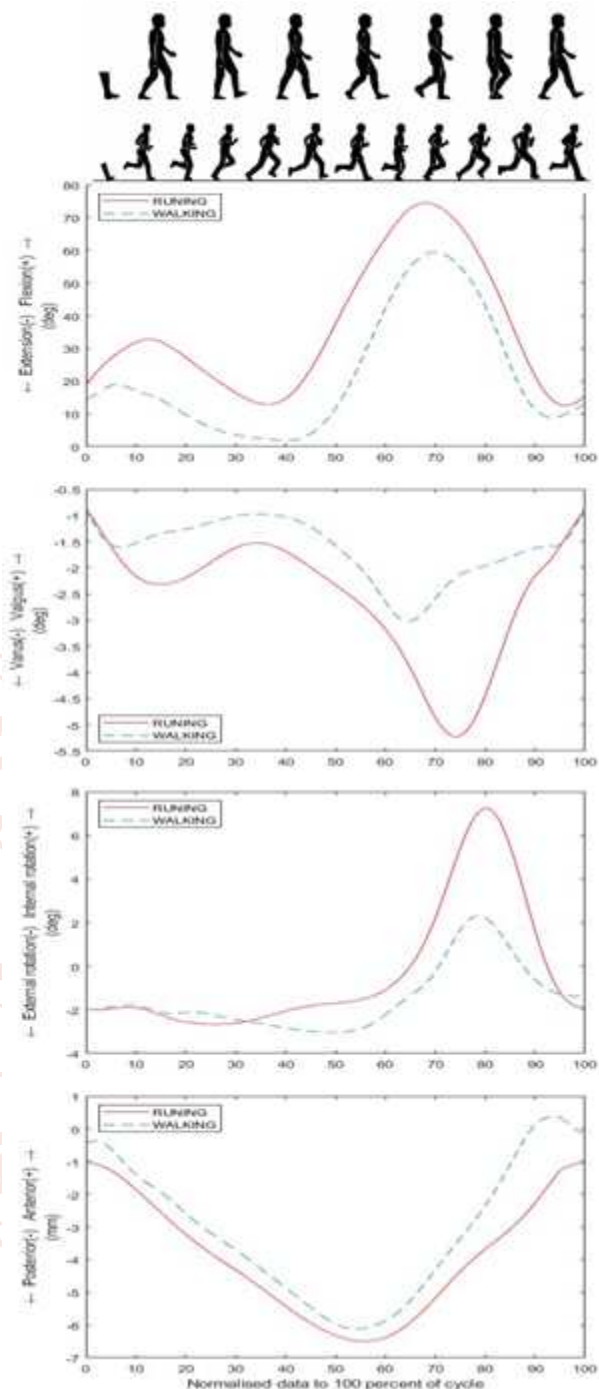


Fig.1. The knee kinematics parameters measured during walking and running. Presenting the average motion data of each participant, which were normalized to 100 points from heel strike to next heel strike of the same foot.

Table 2. Knee kinematic parameters (mean \pm SD).

Variables	Walking	Running	p-value
F/E (deg)	61.0 \pm 4.1	75.4 \pm 4.8	<0.001*
VR/VL (deg)	-4.4 \pm 3.6	-6.8 \pm 3.8	<0.035*
IR/ER (deg)	6.3 \pm 3.1	7.9 \pm 3.5	<0.046*
A/P (mm)	-5.3 \pm 1.1	-5.6 \pm 1.3	0.752*

F/E: flexion/extension; VR/VL: varus/valgus; IR/ER: internal/external femoral rotation; A/P: anterior/posterior tibiai translation; (* Statistically significant difference ($P < 0.05$), t-test, two-tailed.).

DISCUSSION

This study figured out the alterations and differences of knee kinematics during walking and running in middle-age males. As expected the results were supported by the related literature that running demonstrates significantly higher maximum flexion, varus rotation and internal rotation than walking [4-12]. The results showed all maximum parameters occurred during swing phase. It was observed that when the knee started to flex at early swing phase, the tibia internally rotated and medially twisted with a varus angle then slightly shifted to posterior femur.

In running, more flexion angle could have provided a larger stroke length in order to avoid the over extension during support that could increase the injury [4]. An increase in maximum angle of varus rotation and internal rotation could have associated with inertia moment of lower leg, while was put forward and slightly outward before knee extension during swing phase. It could cause external knee adduction moment that was transmitted to the medial compartment of the knee joint. Increased magnitudes of abnormal motion such as varus and internal rotation have been associated with increased lateral knee loading. In support of this, Kumar et al. [10] reported a higher of knee medial compartment loading during gait. Muscles and ligaments must be resisted the load during swing phase repeatedly and may elastically lengthen under the prolonged running time. This could cause the risk of iliotibial friction syndrome [9].

The anteroposterior translation of tibia relative to femur demonstrated harmonic motion. Similar results have been reported in previous study [12]. Although the curves in the translations showed no significant differences, this pattern of motion may cause the shear forces at the tibiofemoral contact interface, enough to produce a cartilage degeneration [13].

CONCLUSION

In conclusion, the altered kinematics performed by middle-age males were similar during walking and running. Running demonstrated higher maximum knee flexion, varus and internal rotation than walking. The increased flexion could have provided a larger stroke length, while varus and internal rotation might have caused by inertia moment of lower leg during swing phase. According to literature review, medial compartment loading from those motion could cause the risk of iliotibial friction syndrome. Although the anteroposterior translations showed no significant differences, the repetitive motion may potentially increase the risk of knee injury,

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