ISSN 2307-8960 (online)

World Journal of *Clinical Cases*

World J Clin Cases 2023 October 16; 11(29): 6974-7260

Published by Baishideng Publishing Group Inc

World Journal of Clinical Cases

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Thrice Monthly Volume 11 Number 29 October 16, 2023

LETTER TO THE EDITOR

ABOUT COVER

Editorial Board Member of *World Journal of Clinical Cases*, Zeid J Khitan, FACP, FASN, MBBS, MD, Academic Research, Director, Full Professor, Department of Medicine, Marshall University, Huntington, WV 25701, United States. zkhitan@marshall.edu

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WJCC mainly publishes articles reporting research results and findings obtained in the field of clinical medicine and covering a wide range of topics, including case control studies, retrospective cohort studies, retrospective studies, clinical trials studies, observational studies, prospective studies, randomized controlled trials, randomized clinical trials, systematic reviews, meta-analysis, and case reports.

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NAME OF JOURNAL
World Journal of Clinical Cases

ISSN
ISSN 2307-8960 (online)

LAUNCH DATE
April 16, 2013

FREQUENCY
Thrice Monthly

EDITORS-IN-CHIEF
Bao-Gan Peng, Jerzy Tadeusz Chudek, George Kontogeorgos, Maurizio Serati, Ja Hyeon Ku

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https://www.wjgnet.com/2307-8960/editorialboard.htm

PUBLICATION DATE
October 16, 2023

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World J Clin Cases 2023 October 16; 11(29): 7061-7074

DOI: 10.12998/wjcc.v11.i29.7061

ISSN 2307-8960 (online)

ORIGINAL ARTICLE

Observational Study

Reference values of gait parameters in healthy Chinese university students: A cross-sectional observational study

Jin-Sheng Yu, Chen Zhuang, Wen-Xuan Guo, Jun-Jie Chen, Xiang-Ke Wu, Wei Xie, Xing Zhou, Hui Su, Yi-Xuan Chen, Li-Kang Wang, Wen-Kai Li, Kun Tian, Ru-Jie Zhuang

Specialty type: Medicine, research and experimental

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's scientific quality classification

Grade A (Excellent): 0
Grade B (Very good): B
Grade C (Good): C
Grade D (Fair): 0
Grade E (Poor): 0

P-Reviewer: Ito S, Japan

Received: July 20, 2023
Peer-review started: July 20, 2023
First decision: August 30, 2023
Revised: September 4, 2023
Accepted: September 18, 2023
Article in press: September 18, 2023
Published online: October 16, 2023

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Abstract

BACKGROUND

Gait is influenced by race, age, and diseases type. Reference values for gait are closely related to numerous health outcomes. To gain a comprehensive understanding of gait patterns, particularly in relation to race-related pathologies and disorders, it is crucial to establish reference values for gait in daily life considering sex and age. Therefore, our objective was to present sex and age-based reference values for gait in daily life, providing a valuable foundation for further research and clinical applications.

AIM

To establish reference values for lower extremity joint kinematics and kinetics during gait in asymptomatic adult women and men.

METHODS
Spatiotemporal, kinematics and kinetics parameters were measured in 171 healthy adults (70 males and 101 females) using the computer-aided soft tissue foot model. Full curve statistical parametric mapping was performed using independent and paired-samples *t*-tests.

RESULTS
Compared with females, males required more time (cycle time, double-limb support time, stance time, swing time, and stride time), and the differences were statistically significant. In addition, the step and stride lengths of males were longer. Compared to males, female cadence was faster, and statures-per-second and stride-per-minute were higher. There were no statistical differences in speed and stride width between the two groups. After adjusting for height, it was observed that women walked significantly faster than men, and they also had a higher cadence. However, in terms of step length, stride length, and stride width, both genders exhibited similarities.

CONCLUSION
We established reference values for gait speed and spatiotemporal gait parameters in Chinese university students. This contributes to a valuable database for gait assessment and evaluation of preventive or rehabilitative programs.

Key Words: Gait analysis; Gait; Reference values; Spatiotemporal parameters; Kinematics; Chinese

Core Tip: In this observational study, gait parameters of healthy Chinese university students were provided, and gender differences in gait as well as differences compared to other ethnicities were observed. These findings may contribute to localized clinical guidance and reference for the region.

Citation: Yu JS, Zhuang C, Guo WX, Chen JJ, Wu XK, Xie W, Zhou X, Su H, Chen YX, Wang LK, Li WK, Tian K, Zhuang RJ. Reference values of gait parameters in healthy Chinese university students: A cross-sectional observational study. *World J Clin Cases* 2023; 11(29): 7061-7074
URL: https://www.wjgnet.com/2307-8960/full/v11/i29/7061.htm
DOI: https://dx.doi.org/10.12998/wjcc.v11.i29.7061

INTRODUCTION

Gait is a fundamental characteristic of human walking, that can be influenced by factors such as race, age, and various diseases. Three-dimensional (3D) motion analysis systems are commonly employed for movement assessments in both clinical and research settings[1,2]. This approach requires a normal reference derived from a healthy population to distinguish it from abnormal conditions. Notably, the reference values may not be universally applicable to every race or age group[3].

In China, approximately 22.7% of college students reported experiencing sports-related injuries in the past year[4]. Lower extremity injuries, including anterior cruciate ligament rupture, acute ankle sprain, and meniscal injury, account for nearly two-thirds of all reported injuries[5-8]. Numerous studies have examined gait changes in both African American and Caucasian populations[9,10]. Gait studies on Asians primarily focused on individuals aged 60 years and above[11,12]. Currently, the reference values for gait among college students remains inconclusive, leadings to overlook early changes in gait and, an increased incidence of osteoarthritis. Three-dimensional motion analysis can serve as an early screening tool for knee osteoarthritis (KOA) and a method of evaluating rehabilitation progress[13].

Due to variations in lower-extremity kinematics and kinetics across different races, ages, and sexes, as well as the limited availability of data on Chinese adults other than the elderly population, this study aimed to investigate three-dimensional lower extremity kinematics and kinetics in healthy Chinese university students. Specifically, we aimed to enhance our understanding of country-specific gait patterns and establish normative data as a reference for lower-extremity movements in all dimensions. Additionally, these new reference values will be beneficial for identifying abnormal motion patterns related to conditions such as chronic ankle instability, deformities, and neuromuscular disorders.

MATERIALS AND METHODS

Study population and data collection

According to previous reports related to gait reference values, a sample size of 30 or more is considered sufficient for normative measurements[12]. In this study, we included participants aged between 18 and 35 years with a body mass index (BMI) between 18.5 and 23.9 kg/m², excluding individuals who were underweight or overweight, based on the World Health Organization's recommended normal weight range. Research has indicated that gait patterns mature around the age of 7 years[14], and certain gait parameters, such as walking speed, tend to decline after the age of 40 years [12]. Therefore, this study focused primarily on university students whose ages fell within the age range associated with mature gait patterns. Written informed consent was obtained from all participants who completed the three health-screening questionnaires prior to participation. In addition, participants were required to engage in exercise for at least 20 minutes, at least three times per week. Individuals with a pathological gait, serious cardiovascular and cerebrovascular diseases, mental and spiritual abnormalities, pregnant and lactating women, or those with contraindications to exercise owing to other medical conditions, were excluded. The inclusion and exclusion criteria are presented in Table 1.

Table 1 Participant inclusion and exclusion criteria

Inclusion	Exclusion
18-35 yr old, BMI: 18.5-23.9 kg/m²	Acute lower limb injury in the past 6 mo
Participation in team sport a minimum of three times a week	Cardiovascular and cerebrovascular diseases
FAAM ≥ 98	History of neurological disease
Lysholm knee score ≥ 95	Pregnant and lactating women
Harris hip score ≥ 95	Balance or motion disorders

BMI: Body mass index; FAAM: Foot and Ankle Ability Measure.

All volunteers provided informed consent before undergoing the motion analysis. Gait analysis was performed using a 3D motion capture system (Qualisys Track Manager, Qualisys, Sweden), consisting of eight high-speed infrared cameras (Oqus700+, Qualisys, Sweden) at a sampling frequency of 1100 Hz. Data were collected by synchronising four Kistler force plates (9260AA; Kistler, Switzerland). Gait data were analysed using modelling and simulation software (Visual 3D Professional V6, C-Motion Incorporation, United States). Lower limbs were analyzed using the Calibrated Anatomical System Technique model[15]. A total of 32 reflective markers were attached to the participants' bony landmarks and placed on the skin surface. Elastic bandages were used to secure the marker plates on the lateral upper two-thirds of the thigh and calf with four reflective markers on each plate. Before commencing data collection, the participants were familiarised with the walking procedure. This involved practising walking at their preferred speed within a 2-meter range in front of and behind the Kistler force plate recording area. The participants completed three rounds of practice walking to minimise the potential impact of acceleration and deceleration on the results. After ensuring that the participants were familiar with the walking procedure and that all the reflective markers were detected, the data from the three best gait cycles were averaged to calculate the joint angles for each participant. Gait speed (m/s), stride length (m), and stride width (m) were assessed, and kinematic and kinetic parameters were simultaneously recorded during the gait analysis.

Data on age, sex, weight (kg), height (cm), BMI (kg/m²), cadence, speed, cycle, stance, and swing times were collected. To ensure accuracy, we calibrated and corrected the geodetic coordinate systems and positions of the eight cameras. Subsequently, static and dynamic data were collected. For the dynamic data, we selected eight consecutive gait cycles performed by the participants at their preferred walking speeds, starting from the beginning of each walking trial. Data from each gait cycle were processed to represent the 0%–100% gait cycle. Finally, we averaged the values from the eight gait cycles to evaluate the kinematics and kinetics of the ankle, knee, and hip joints in each participant.

Statistical analysis

As height affects certain gait parameters, we normalised specific gait parameters based on height. Height-adjusted gait speed (gait speed/height)[16], height-adjusted step length (step length/height)[17], height-adjusted stride length (stride length/height), and height-adjusted stride width (stride width/height) were normalised to account for height, while height-adjusted cadence was normalised using the square root of height$^{(\text{cadence} \times \sqrt{\text{height}})}$[18].

All parameters are described using means and standard deviations, and the data were analysed using SPSS 25.0. An independent sample *t*-test was employed for data conforming to a normal distribution, whereas the rank sum test was used for data that did not conform to a normal distribution. Statistical parametric mapping (SPM) was conducted to visualise the complete time series of angle, moment, and power assessments. Two-tailed paired *t*-tests were used to compare kinematics and kinetics. SPM analyses were performed in MATLAB (R2020b, The MathWorks Inc) using an open-source code (M.0.4.8, www.spm1d.org). The significance level was set at P = 0.05.

Table 2 Participants demographic data

Characteristics	Female	Male	Total
Age (yr), mean (SD)	24.50 (2.18)	24.81 (2.19)	24.63 (2.19)
Gender (*n*, %)	101 (59.06%)	70 (40.93%)	
Height (m), mean (SD)	1.62 (0.0)	1.75 (0.05)	1.68 (0.08)
Weight (kg), mean (SD)	52.14 (5.10)	67.90 (7.93)	58.59 (10.06)
BMI (kg/m^2), mean (SD)	19.72 (1.89)	21.87 (1.86)	20.64 (2.16)
FAAM, mean (SD)	100 (0.00)	100 (0.00)	100 (0.00)
Lysholm knee score, mean (SD)	100 (0.00)	100 (0.00)	100 (0.00)
Harris hip score, mean (SD)	100 (0.00)	100 (0.00)	100 (0.00)

BMI: Body mass index; FAAM: Foot and Ankle Ability Measure.

Table 3 Spatiotemporal parameters

Variables	Mean (SD)		*P* value
	Male	Female	
Cadence (steps/min)	113.35 (11.05)	118 (7.63)	< 0.05
Height-adjusted cadence	1503.74 (151)	1539.60 (80)	< 0.05
Speed (m/s)	1.24 (0.17)	1.22 (0.11)	0.35
Height-adjusted gait speed (cm/s)	0.70 (0.09)	0.76 (0.06)	< 0.05
Step length (m)	0.66 (0.09)	0.62 (0.05)	< 0.05
Height-adjusted step length (cm)	0.37 (0.05)	0.38 (0.02)	0.60
Stride length (m)	1.31 (0.13)	1.24 (0.29)	< 0.05
Height-adjusted stride length (cm)	0.75 (0.07)	0.76 (0.05)	0.30
Stride width (m)	0.11 (0.03)	0.10 (0.03)	0.07
Height-adjusted stride width (cm)	0.06 (0.01)	0.06 (0.01)	0.42
Cycle time (sec)	1.07 (0.09)	1.01 (0.07)	< 0.05
Double limb support time (sec)	0.23 (0.04)	0.21 (0.03)	< 0.05
Stance time (%GC)	0.65 (0.06)	0.61 (0.05)	< 0.05
Swing time (%GC)	0.42 (0.04)	0.40 (0.03)	< 0.05
Statures-per second	0.71 (0.10)	0.77 (0.08)	< 0.05
Stride time (sec)	1.08 (0.08)	1.02 (0.08)	< 0.05
Stride-per minute	55.94 (4.65)	59.72 (3.40)	< 0.05

GC: Gait cycle.

RESULTS

In total, 171 volunteers participated in this study, with an average age of 24.63 ± 2.19 years. Of them, 101 (59%) were female. The mean height was 1.68 ± 0.08 cm, and the mean weight was 58.59 ± 10.06 kg. The average BMI was 20.60 ± 2.15 kg/m^2. The demographic data are presented in Table 2.

Spatiotemporal parameters

The spatiotemporal parameters of the participants are listed in Table 3. Compared with females, males required more time in terms of cycle time, double-limb support time, stance time, swing time, and stride time, with statistically significant differences. In addition, males exhibited longer steps and stride lengths. Conversely, females demonstrated faster cadence, higher steps per second, and more strides per minute than males. There were no statistically significant

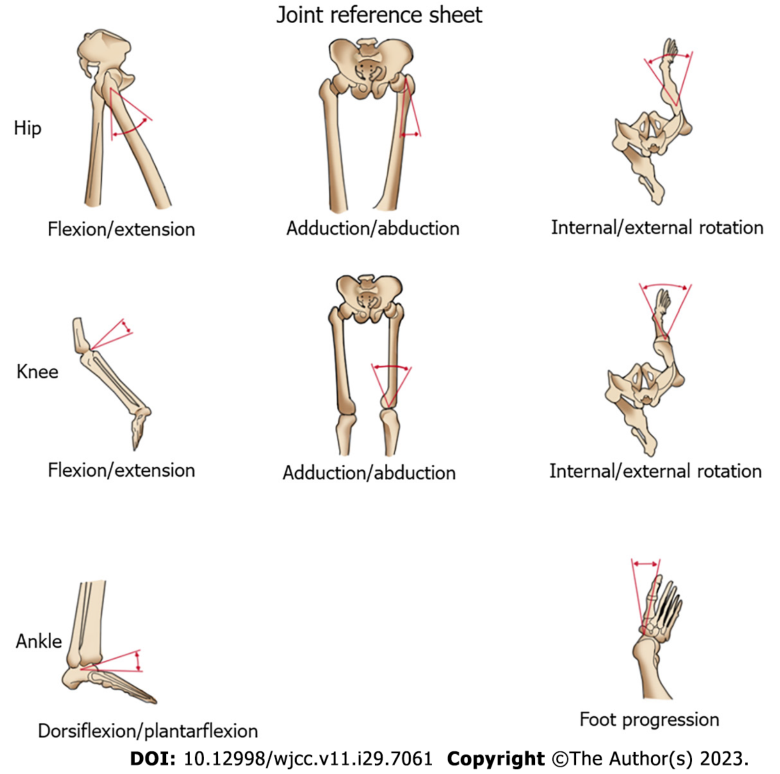


Figure 1 Illustrations of the hip, knee, and ankle joint movements in different planes.

differences in speed or stride width between the sexes. However, after adjusting for height, women walked significantly faster than men (0.06 m/s, P < 0.05) (Table 3). Additionally, even after height adjustment, women maintained a significantly higher cadence than did men (P < 0.05), whereas the significant differences in step and stride lengths between men and women disappeared. There were no significant differences in the stride width between men and women.

Kinematic and kinetic parameters

As shown in Figure 1, we gathered the motion parameters for the hip, knee, and ankle joints in various planes. Significant differences were observed in the joint kinematics and kinetics of the ankles, knees, and hips among all participants. The detailed kinematics and kinetics of the ankle, knee, and hip are shown in Figures 2, 3, and 4, respectively.

Hip joint

Regarding the hip joint, sex-based differences were significant in sagittal hip flexion from 0%–13% and from 75%–100% of the gait cycle (P = 0.030 and P = 0.007, respectively). Moreover, significant differences were observed in the frontal plane of the hip joint during the 4%–21% (P = 0.015), 57%–66% (P = 0.034), and 86%–91% (P = 0.043) gait cycles. In the transverse planes of motion, significant differences were observed between the groups from 78%–100% of the gait cycle (P = 0.009).

No significant differences were observed in peak hip extensor moment during the early stance. However, significant differences were observed between 67% and 77% of the gait cycles (P < 0.001). Significant differences in hip power were observed during 68%–77% of the gait cycle (P < 0.001). No significant differences were observed in hip abductor moment.

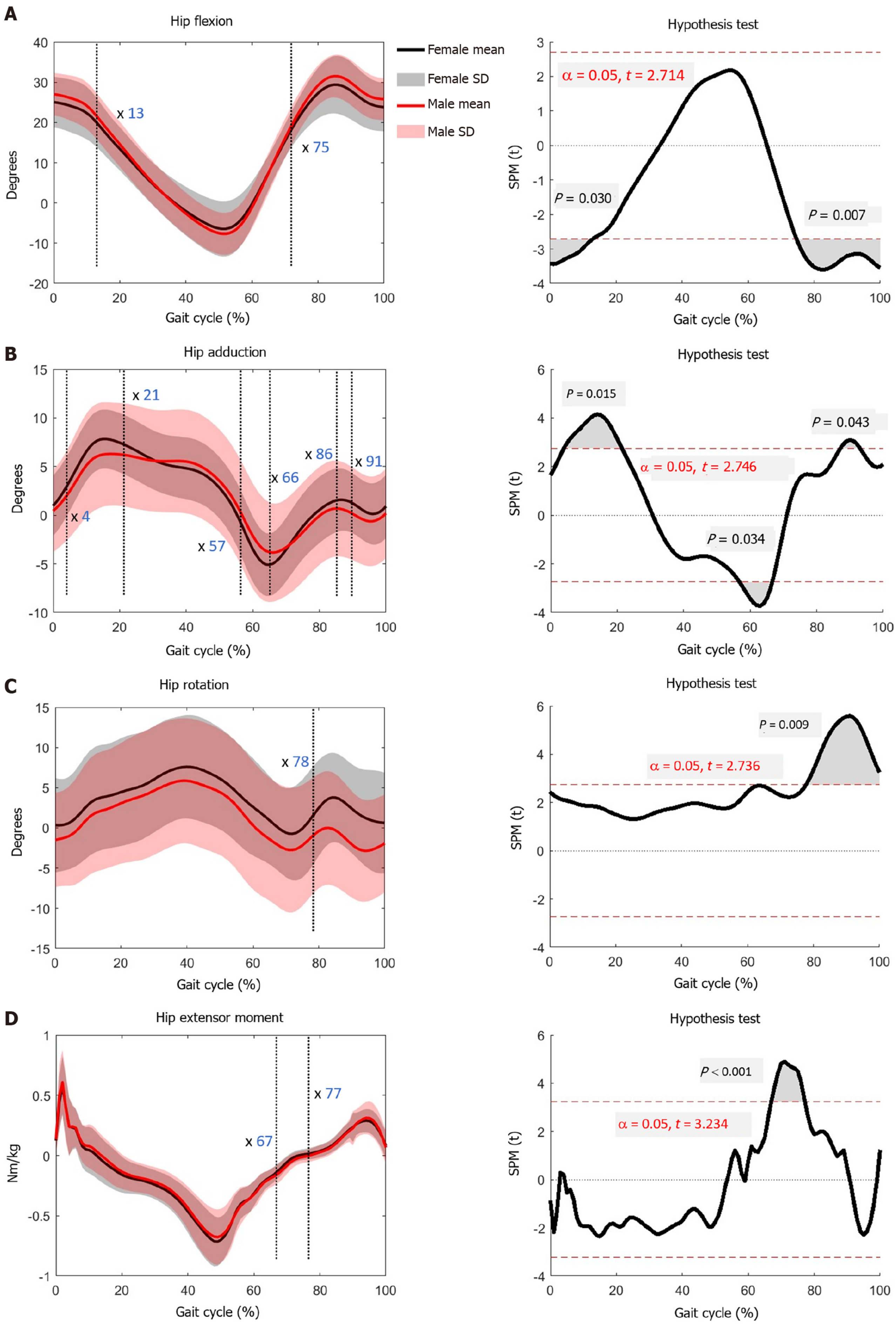
Knee joint

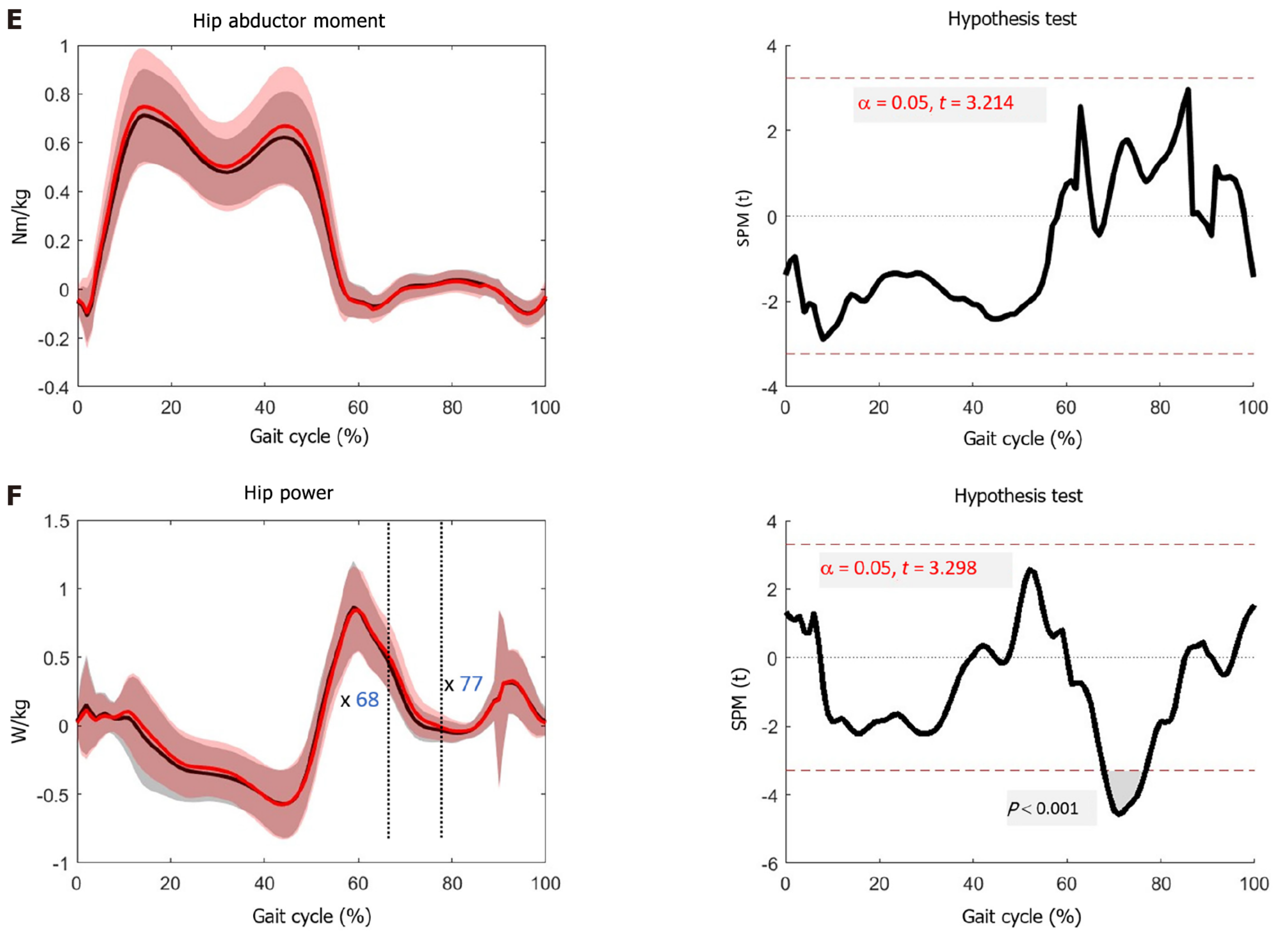
At the knee joint, a significant sex-based difference was observed in sagittal knee flexion from 0%–100% of the gait cycle (P < 0.001), indicating differences in the range of knee movements during walking. However, no significant differences were observed in the frontal knee adduction. In the transverse planes of motion, particularly during 90%–97% of the gait cycle, there was high variability among the participants (P = 0.028).

Regarding knee kinetics, no statistically significant differences were detected in the knee extensor moment or knee power. However, differences were observed between the two smaller intervals in knee valgus moment (P = 0.018 and P = 0.046, respectively).

Ankle joint

At the ankle joint, no significant sex-based differences were observed in the ankle plantarflexion, dorsiflexion, inversion, or eversion. However, significant sex differences were found in the ankle eversion moment at the initial contact (P < 0.001) and from 58%–62% of the gait cycle (P = 0.013). No significant differences were detected in ankle plantarflexor


A
Hip flexion
Female mean
Female SD
Male mean
Male SD
x 13
x 75
Degrees
Gait cycle (%)
Hypothesis test
α = 0.05, t = 2.714
P = 0.030
P = 0.007
SPM (t)
Gait cycle (%)
B
Hip adduction
x 21
x 4
x 57
x 66
x 86
x 91
Degrees
Gait cycle (%)
Hypothesis test
P = 0.015
P = 0.043
α = 0.05, t = 2.746
P = 0.034
SPM (t)
Gait cycle (%)
C
Hip rotation
x 78
Degrees
Gait cycle (%)
Hypothesis test
P = 0.009
α = 0.05, t = 2.736
SPM (t)
Gait cycle (%)
D
Hip extensor moment
x 67
x 77
Nm/kg
Gait cycle (%)
Hypothesis test
P < 0.001
α = 0.05, t = 3.234
SPM (t)
Gait cycle (%)



DOI: 10.12998/wjcc.v11.i29.7061

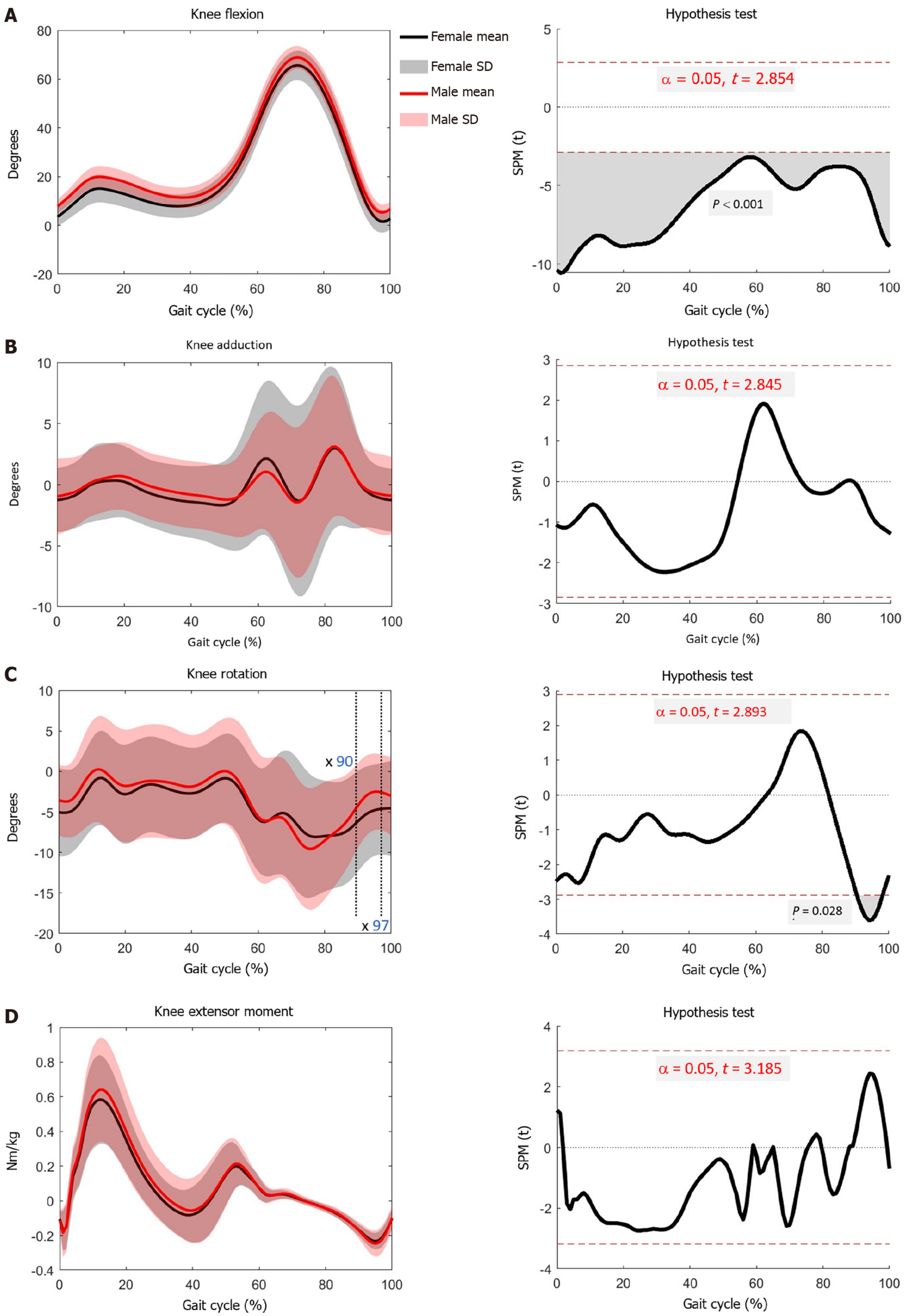
Figure 2 Joint angle, moment and power of hip. A: Angle of hip flexion and extension movements in males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the angles of flexion and extension. Positive values indicated flexion, whereas negative values indicated extension. Statistical Parametric Mapping compared the differences between males and females throughout the complete gait cycle, and differences with $P < 0.05$ were considered statistically significant; B: Angle of hip adduction and abduction movements in males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the angles of adduction and abduction. Positive values indicated adduction, whereas negative values indicated abduction; C: Angle of hip internal and external rotation movements for males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the angles of internal and external rotation. Positive values indicated internal rotation, whereas negative values indicated external rotation; D: Flexor and extensor moments of the hip joint for males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the magnitude of the moment. Positive values represented the extensor moment, whereas negative values represented the flexor moment; E: Abductor and adductor moments of the hip joint for males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the magnitude of the moment. Positive values represent abductor moments, whereas negative values represent adductor moments; F: Hip power in males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the magnitude of power. Positive values represent power generation whereas negative values represent power absorption. SPM: Statistical parametric mapping.

moment or ankle power.

DISCUSSION

Spatiotemporal parameters

In this study, we established inclusion and exclusion criteria based on previous research on gait reference values[11,12]. Furthermore, we utilized three assessment tools to evaluate the physical activity functionality of participants. These tools include the Foot and Ankle Ability Measure, designed to assess the muscular and musculoskeletal function of the lower extremities, feet, and ankle joints[19]; the Lysholm knee score, employed to evaluate general knee joint conditions and functionality[20,21]; and the Harris Hip Score, utilized to assess hip pathology and health-related quality of life in daily activities[22,23]. All three assessment tools were validated as responsive, reliable, and effective evaluation instruments; thus, supporting the definition of a healthy population and a mature gait pattern. Building on this foundation, we investigated the spatiotemporal parameters, kinematics, and kinetics of the gait of Chinese college students. We observed that women had significantly faster cadence, higher statures-per-second, and strides-per-minute, accompanied by longer step lengths. However, women exhibited significantly shorter stride, step, cycle, double-limb support, stance, swing, and stride times than men did. No significant sex differences were observed in speed or stride width. After adjusting for


A
Knee flexion
Female mean
Female SD
Male mean
Male SD
Degrees
Gait cycle (%)
Hypothesis test
α = 0.05, t = 2.854
P < 0.001
SPM (t)
Gait cycle (%)
B
Knee adduction
Degrees
Gait cycle (%)
Hypothesis test
α = 0.05, t = 2.845
SPM (t)
Gait cycle (%)
C
Knee rotation
x 90
x 97
Degrees
Gait cycle (%)
Hypothesis test
α = 0.05, t = 2.893
P = 0.028
SPM (t)
Gait cycle (%)
D
Knee extensor moment
Nm/kg
Gait cycle (%)
Hypothesis test
α = 0.05, t = 3.185
SPM (t)
Gait cycle (%)

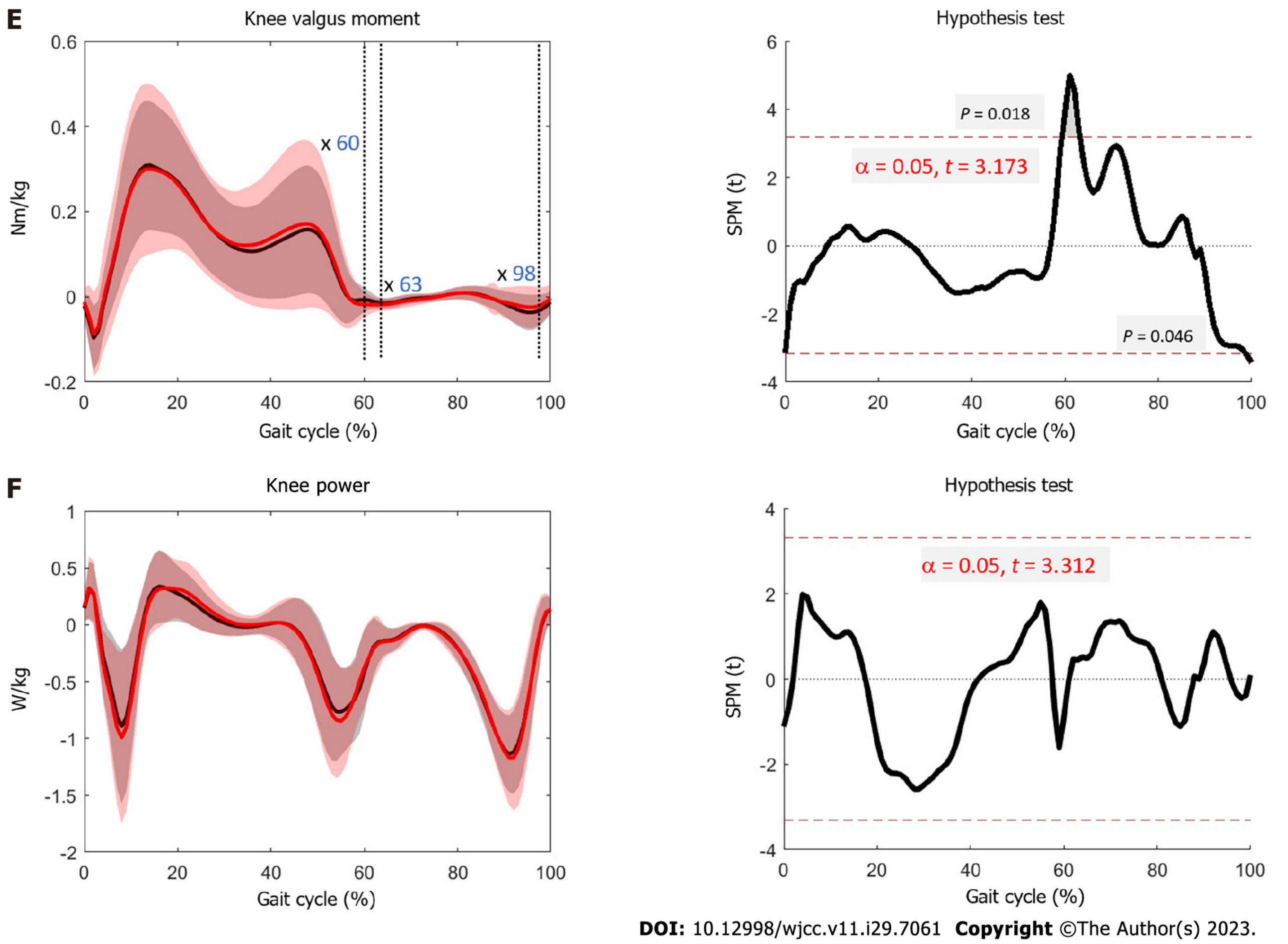
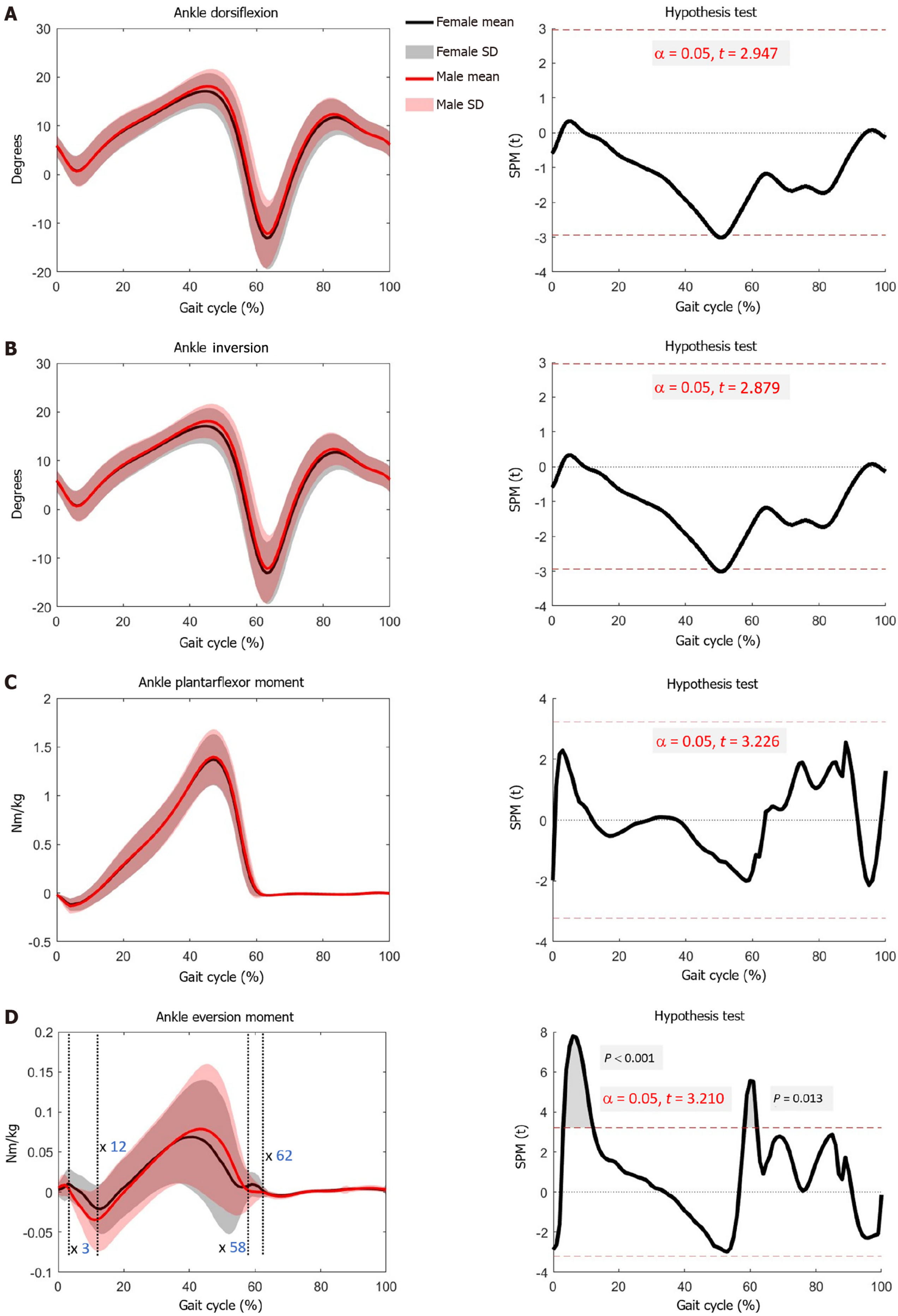


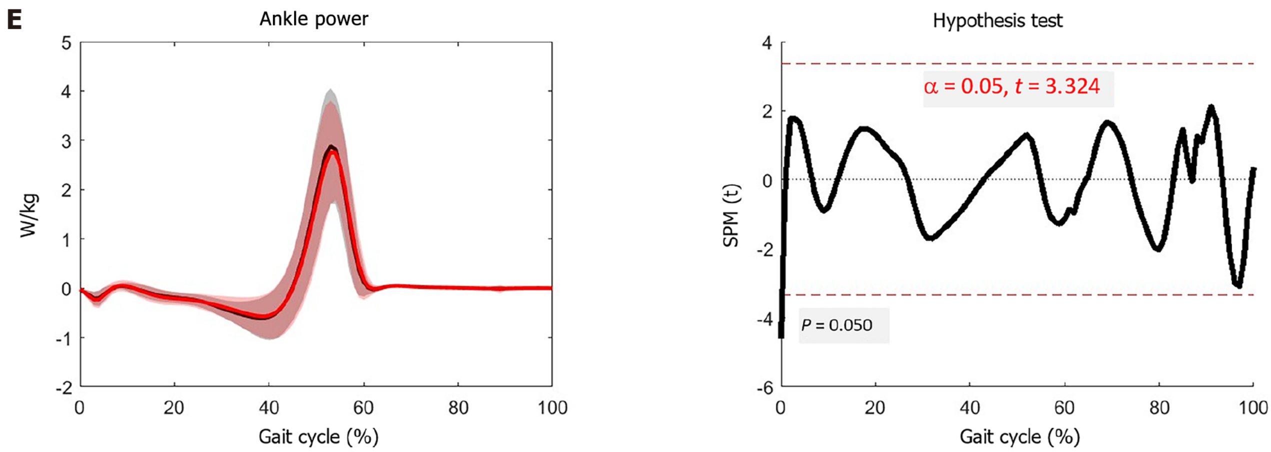
Figure 3 Joint angle, moment and power of knee. A: Angle of knee flexion and extension movements in males and females, with the horizontal axis representing a complete gait cycle and the vertical axis representing the angles of flexion and extension. Positive values indicated flexion, whereas negative values indicated extension. Statistical Parametric Mapping compared the differences between males and females throughout the complete gait cycle, and differences with $P < 0.05$ were considered statistically significant; B: Angle of knee adduction and abduction movements for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the angles of adduction and abduction. Positive values indicate adduction, whereas negative values indicate abduction; C: Angle of knee internal and external rotation movements for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the angles of internal and external rotation. Positive values indicate internal rotation, whereas negative values indicate external rotation; D: Flexor and extensor moments of the knee joint for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the magnitude of the moment. Positive values represent extensor moment, whereas negative values represented the flexor moment; E: Valgus and varus moments of the knee joint for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the magnitude of the moment. Positive values represent valgus moment, whereas negative values represent varus moment; F: Knee power in males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the magnitude of power. Positive values represent power generation, whereas negative values represent power absorption. SPM: Statistical parametric mapping.

height, it became evident that women walked significantly faster than men (0.06 m/s, $P < 0.05$) (Table 3). Importantly, even when height differences were considered, women still exhibited a significantly higher cadence than men ($P < 0.05$). Interestingly, the previously observed significant differences in the step and stride lengths between males and females disappeared. Regarding stride width, no significant differences were found between men and women. These findings on sex differences in cadence, gait speed, and cycle time are consistent with previous studies conducted in laboratory settings, which reported that women had a faster cadence and shorter cycle time than men[24]. Compared to individuals from the Southeast Asian region, our study found that Chinese participants had slightly faster walking speeds (men: 1.14 m/s for Southeast Asians, 1.24 m/s for Chinese; women: 1.13 m/s for Southeast Asians, 1.22 m/s for Chinese)[12]. However, sex differences in stride width tended to be similar to those observed in Southeast Asian population. Additionally, the Chinese participants in our study exhibited longer step lengths and shorter double-limb support times than the Southeast Asian population. Furthermore, they exhibited faster cadence compared to Southeast Asian and Korean populations[25]. A faster cadence can lead to increased wear of the knee joint, which may contribute to the incidence and risk factors of symptomatic KOA in Chinese women[26].

Kinematic and kinetic data

Our findings demonstrated significant sex-based differences in the kinematic and kinetic gait features of the three major lower-limb joints. These differences were primarily observed in the hip and knee joints rather than the ankle joint, indicating overall pattern differences throughout the gait cycle. Compared to previous studies, our results also showed


A
Ankle dorsiflexion
Degrees
Gait cycle (%)
Female mean
Female SD
Male mean
Male SD
Hypothesis test
α = 0.05, t = 2.947
SPM (t)
Gait cycle (%)
B
Ankle inversion
Degrees
Gait cycle (%)
Hypothesis test
α = 0.05, t = 2.879
SPM (t)
Gait cycle (%)
C
Ankle plantarflexor moment
Nm/kg
Gait cycle (%)
Hypothesis test
α = 0.05, t = 3.226
SPM (t)
Gait cycle (%)
D
Ankle eversion moment
Nm/kg
x 3
x 12
x 58
x 62
Gait cycle (%)
Hypothesis test
P < 0.001
α = 0.05, t = 3.210
P = 0.013
SPM (t)
Gait cycle (%)



DOI: 10.12998/wjcc.v11.i29.7061

Figure 4 Joint angle, moment and power of ankle. A: Angle of ankle dorsiflexion and plantarflexion movements for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the angles of dorsiflexion and plantarflexion. Positive values indicate dorsiflexion, whereas negative values indicate plantarflexion. Statistical Parametric Mapping compared the differences between males and females throughout a complete gait cycle, and differences with $P < 0.05$ were considered statistically significant; B: Angle of ankle inversion and eversion movements for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the angles of inversion and eversion. Positive values indicate inversion, while negative values indicate eversion; C: Plantarflexor and dorsiflexor moments of the ankle joint for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the magnitude of the moment. Positive values represent plantarflexor moment, whereas negative values represent dorsiflexor moment; D: Eversion and inversion moment of the ankle joint for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the magnitude of the moment. Positive values represent eversion moment, whereas negative values represent inversion moment; E: Ankle power for males and females, with the horizontal axis representing a complete gait cycle, and the vertical axis representing the magnitude of power. Positive values represent power generation, whereas negative values represent power absorption. SPM: Statistical parametric mapping.

variations in gait patterns. Previous studies have consistently shown that females exhibit lower overall transverse plane hip internal rotation angles[27], and smaller ankle plantarflexor moments throughout most stance phases[25]. In contrast, our findings revealed that females had higher overall transverse plane hip internal rotation angles and no significant differences were observed in ankle plantarflexor moments. These discrepancies may be attributed to the variations in the gait speed of the participants. Although there are differences between men and women in many gait features, the effect sizes of some of these differences are relatively small; therefore, individual features may not fully explain these significant differences. However, when these small differences were considered, an overall difference in gait cycle between healthy males and females becomes evident. Our findings are in agreement with those of previous studies that investigated sex differences in gait kinematics among older adults[28-30]. Specifically, in our study, healthy females exhibited significantly greater hip adduction during the stance phase of gait than healthy males. Our results are similar to most previous studies that reported differences in the sagittal, frontal, and transverse plane hip joint angles between younger healthy males and females during walking[31,32]. In contrast to investigations involving healthy middle-aged and older adults[25,33], our study found no significant differences in knee adduction angles, or ankle plantarflexion and inversion angles between healthy younger males and females. These contradictory findings may be attributed to subtle changes in gait associated with biological aging[34]. The mean age of the participants in the current study was 24.92 ± 2.25 years, while the aforementioned studies, included adults in their forties or sixties. Therefore, the sex-specific gait kinematic differences in healthy younger adults differ from those previously found in healthy older adults.

In this study, spatiotemporal gait parameters, as well as kinetic and kinematic parameters were analyzed to assess sex differences and movement patterns. Future studies should investigate the impact of age on gait parameters using a comprehensive curve analysis to identify group differences. Additionally, these analytical methods should be employed to investigate dynamic motion and its association with various conditions such as changes in orientation and gait patterns during single- and double-leg landing, running, and KOA. Examining movement patterns across different activities can provide a better understanding of potential disparities between men and women. This could be particularly relevant for patients with KOA because women have a higher incidence of this condition.

This study has several limitations. First, the small sample size prevented us from conducting intragroup analysis based on sex. Future studies with larger sample sizes are needed to comprehensively investigate the potential sex differences within each group. Secondly, this study only captured gait information during a single period. Future studies should consider collecting gait data from the same individuals in different age groups to examine gait across different age ranges. Finally, our study did not report any specific muscle activity during walking. Future equipment improvements will allow for a more comprehensive analysis of the lower limb muscle work and other related parameters.

CONCLUSION

This study aimed to investigate the motion parameters of the hip, knee, and ankle joints in Chinese adults aged 18–35 years. These findings highlighted the importance of considering sex-based differences in gait biomechanics in future studies. Our results indicated significant differences between men and women in the range of motion of the knee joint in the sagittal plane, whereas smaller differences were observed in the range of motion of the hip joint. No significant differences were observed in the ankle joint range of motion between males and females, suggesting a potentially distinct gait pattern for each sex. Although our study focused on Chinese college students, further population-based research is recommended to explore gait parameters across different age groups.

ARTICLE HIGHLIGHTS

Research background

Gait refers to the movement patterns and rhythms of various body parts during walking, making it a crucial indicator of human movement and overall health. Currently, there is a relatively limited studies on the gait characteristics of Chinese male and female populations. To address this gap and provide more precise reference values for the region, we aimed to collect gait data from healthy Chinese university students and conduct a comprehensive analysis of sex-based differences.

Research motivation

Through this study, we aimed to reveal the commonalities and disparities in gait between Chinese men and women, thereby providing a more accurate foundation and reference for future clinical diagnosis and treatment. This research could have a positive impact on improving diagnosis and rehabilitation measures for relevant conditions, as well as optimizing sports training and exercise rehabilitation programs.

Research objectives

We collected gait data from healthy university students in China and conducted a detailed analysis of their gait characteristics, including stride length, step frequency, and gait cycle. Through this study, we will gain a deeper understanding of sex-based differences in the gait characteristics of male and female individuals in China, providing valuable data and guidance for medical and rehabilitation practices in this region. Additionally, these findings have the potential to optimize sports training and exercise rehabilitation programs, and promote overall health and physical performance.

Research methods

A total of 171 volunteers participated in this study, with an average age of 24.63 ± 2.19 years. Baseline data of the participants were collected, including gender, age, height, weight, body mass index, Foot and Ankle Ability Measure, Lysholm knee score, and Harris hip score. Gait data were captured using the Qualisys three-dimensional motion capture system. Data analysis was conducted using SPSS 25.0 and MATLAB (R2020b, The MathWorks Inc).

Research results

In this study, significant differences were observed between males and females in the range of motion of the knee joint in the sagittal plane, while smaller differences were observed in the range of motion of the hip joint. No significant differences were observed in the range of motion of the ankle joint between males and females, suggesting the existence of potentially distinct gait patterns for each sex. This study provides more accurate evidence for future clinical diagnosis and treatment.

In future studies, we will increase the sample size and collect gait data from the same participants in different age groups to study changes in gait across various age ranges.

Research conclusions

This study utilized statistical parameter mapping to analyze the gait characteristics of males and females throughout the gait cycle, providing motion parameters for the hip, knee, and ankle joints. These findings highlighted the importance of considering sex-based differences in gait biomechanics in future studies.

Research perspectives

When guiding treatment plans, healthcare providers should be vigilant of the varying expectations of different sexes and racial or ethnic groups. Considering these expectations is crucial to enhance patient compliance and improve treatment outcomes.

ACKNOWLEDGEMENTS

We express our heartfelt gratitude to the Gait Analysis Laboratory at Zhejiang Traditional Chinese Medicine Hospital for providing the necessary resources and facilities, which greatly facilitated the progress of this study. We sincerely appreciate the cooperation, advice, and assistance of the research team members in data collection and analysis. We also extend our gratitude to the volunteers who willingly participated in this study. We are deeply thankful to the aforementioned individuals and organizations for their invaluable support and contributions, which were vital in achieving the objectives of this research.

FOOTNOTES

Author contributions: Zhuang RJ and Tian K are guarantors and designed this study; Zhuang C, Guo WX, and Yu JS were involved in data acquisition, analysis, and interpretation; Zhuang C and Yu JS drafted the initial manuscript; Chen JJ, Wu XK, Xie W, Zhou X, Su Hui, Chen YX, Wang LK, Li WK revised the article critically for important intellectual content.

Supported by Major Project of the Co-construction Science and Technology Program between the Science and Technology Department of the National Administration of Traditional Chinese Medicine and the Zhejiang Administration of Traditional Chinese Medicine, No. GZY-ZJ-KJ-23040; Zhejiang Medical and Health Science and Technology Project, No. 2022497035; Quzhou City Science and Technology Project, No. 2022K75; Zhejiang Chinese Medical University Scientific Research Fund Project, No. 2021FSYYZZ09, No. 2021FSYYZZ14.

Institutional review board statement: The study was reviewed and approved by the Department of Orthopedics, The First Affiliated Hospital of Zhejiang Chinese Medical University (Zhejiang Provincial Hospital of Traditional Chinese Medicine) Institutional Review Board [Approval No. 2023-K-162-01].

Informed consent statement: All study participants provided informed written consent prior to study enrollment.

Conflict-of-interest statement: The authors have no conflict of interest in regards to this work.

Data sharing statement: Data can be obtained from the corresponding author upon request.

STROBE statement: The authors have read the STROBE Statement—checklist of items, and the manuscript was prepared and revised according to the STROBE Statement—checklist of items.

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S-Editor: Lin C
L-Editor: A
P-Editor: Yu HG

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