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The impact of body mass index on the active range of motion of the lower extremity in sedentary young adults

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Abstract

Introduction. The study aimed to investigate the impact of body mass index (BMI) on the active range of motion (AROM) of the lower extremity joints in healthy sedentary young adults.

Methods. Overall, 300 subjects of both genders (aged 18–30 years) were recruited in a way ensuring that the 4 BMI categories (underweight, normal, overweight, and obese) were well represented within the study sample. AROM of hip (flexion, extension, abduction, adduction, external and internal rotation), knee (flexion and extension), and ankle (dorsiflexion and plantar flexion) were measured by using standard manual goniometry. The average of 3 repetitions for each joint movement was recorded.

Results. Hip and knee sagittal movement and ankle dorsiflexion were significantly different between the BMI categories. The underweight and normal participants had statistically significantly highest AROM measures when compared with the overweight and obese individuals. Sagittal hip (flexion: $r = -0.344$, $p < 0.001$; extension: $r = -0.291$, $p < 0.001$) and knee ($r = -0.544$, $p < 0.001$), as well as hip abduction ($r = -0.127$, $p = 0.027$) movements exhibited a significant negative correlation with BMI. Rotational hip and ankle joint movements were not correlated with BMI.

Conclusions. Increasing BMI limits the sagittal AROM of the hip and knee joints in sedentary healthy young adults. Obesity and overweight could be listed among the factors affecting sagittal hip and knee AROM.

Key words: body composition, body mass index, goniometry, lower extremity, range of motion

Introduction

Obesity is an important epidemic problem in the modern world. Its spread increases in developed [1, 2] and developing countries [3, 4] across all age groups [5]. The accumulation of fat in the human body can raise the risk of many health problems, such as diabetes, heart diseases [6], respiratory disorders [7], skin diseases [8], and decreased physical functioning [9]. Flexibility is one of the parameters that reflect the level of physical functioning [10]. Flexibility can be determined by measuring the functional length of a muscle or the available range of motion (ROM) in a joint [11].

Joint ROM is an important component in the fields of orthopaedics, physical therapy, and sport [12, 13]. This measure gives an overview of the integrity of the joint and the surrounding soft tissues; it also helps assess the quality of different therapeutic interventions and document treatment progress [14]. Furthermore, the designation of an efficient work environment relies to a high extent on joint ROM data [15, 16].

The human body needs the joints to move within their anatomical ranges to be able to achieve different tasks. Without normal ROM, the subject will lose the ability to perform important daily life activities, such as walking, stair climbing, changing clothes. Social, occupational, and recreational activities will be also affected by limitations in ROM [14]. Joint ROM limitations have been associated with deterioration in individuals' physical, psychological, and financial status, as well as quality of life [17].

Although the influence of obesity on joint ROM seems logical, little is known about the impact of obesity on different lower extremity joints [18]. Body fat usually deposits in the abdominal, thigh, gluteal, and calf areas [19]. The accumulation of fat in these regions can affect the degree of mobility in the lower extremity and may hinder a great amount of the anatomical joint range. Hip and knee joints mobility seems to exhibit a greater risk of limitations due to increased body fat [14], yet the results are still not conclusive.

The literature contains few studies that tended to examine the influence of body mass index (BMI) on joint ROM. Moreover, these studies have some limitations, such as using a small sample size [16, 19], lack of presentation of different BMI categories [16], not covering all lower extremity joints [19], or involving the adult age group [13, 20].

Therefore, this study aimed to investigate the impact of BMI on the active ROM (AROM) of the lower extremity joints in healthy sedentary young adults.

Subjects and methods

Study design and sample

This cross-sectional, between-group observational study was performed between January and March 2019 in the Cairo University Research Laboratory. A convenient sample of 300 healthy sedentary Egyptian subjects aged 18–30 years (150 males, mean age: 22.31 ± 3.84 years; 150 females, mean age: 23.13 ± 3.79 years were recruited from the local community through social media announcements (posts on Facebook, WhatsApp, and Twitter). Sedentary subjects were operationally defined as those who performed less than 150 minutes of moderate-intensity exercises per week [19, 21].

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Active persons, pregnant women, women with a history of pregnancy, subjects with previous lower extremity surgery or deformity, and those with neuromusculoskeletal disorders or changes in weight due to hormonal diseases or any other pathological conditions were excluded.

Initial assessment

An independent research assistant performed the initial interview. During this interview, the purpose of the study was described, any inquiries were answered, screening for inclusion and exclusion criteria was conducted. A consent form was then signed by the individuals who met the eligibility criteria and agreed to participate. Demographic data (age, weight, height) were collected, and BMI was calculated. The participants were allocated in one of the 4 groups (underweight, normal, overweight, and obese) depending on their BMI value.

The weight and height were measured by using weight scales and a stadiometer, respectively. BMI was calculated in accordance with the formula: weight (kg) / height $(m)^2$ [22].

BMI represents the gold standard method to distinguish between normal and abnormal body composition [23]. According to the World Health Organization [24], BMI below 18.5 kg/m^2 denotes underweight, BMI below 25 kg/m^2 denotes normal weight, BMI of 25 kg/m^2 or above denotes pre-obesity (overweight), and BMI of 30 kg/m^2 or above denotes obesity.

Range of motion measurement

A therapist with a 15-year experience (who was blinded to the personal characteristics and BMI category of the participants) assessed the AROM of the hip, knee, and ankle joints in both lower extremities of the subjects. Each movement was measured 3 times with a standard 30-cm armed goniometer. The validity and reliability of the manual goniometer had been documented for the measurement of joint ROM [25, 26].

The goniometric measurement procedures were performed in accordance with the guidelines described by Norkin and White [27] and are summarized in Table 1.

After adjusting the participant's position and placing the goniometer on the predetermined landmarks, the individual was instructed to actively move the joint through full ROM. Each joint movement was repeated 3 times and the sequence of measurements was random to avoid memorizing the previously measured ROM values. The mean of 3 measurements was recorded and the angle was approximated to the nearest 1° [16].

Statistical analysis

The recorded data were statistically analysed by using the SPSS software, version 21 (SPSS, Chicago, USA). Descriptive statistics, including mean ± standard deviation and 95% confidence interval, were calculated for all the outcome variables. One-way ANOVA test was applied to compare the participants' data between the 4 BMI categories for the entire sample and with gender-based stratification. When a significant difference was detected, post-hoc pairwise comparisons were performed with Tukey's honestly significant difference test. To test the assumptions for correlation, the normal distribution of the outcome variables was examined by using the Shapiro-Wilk test. Since the data were not normally distributed ($p < 0.05$), Spearman's rank-order correlation coefficient (ρ) was applied to evaluate the correlation between BMI and the goniometric measurements of hip, knee, and ankle AROM. The significance level was set at $p < 0.05$.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Faculty of Physical Therapy, Cairo University ethics committee (approval No.: P.T.REC/012/001698).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The participants' demographic data and AROM measures depending on BMI categories are presented in Tables 2 and 3. The entire sample consisted of 300 participants: 150 males (50%) and 150 females (50%). The 4 BMI categories presented significant differences in terms of the participants' weight and BMI data. Height was also significantly different; however, the difference in height was trivial and did not exceed 3 cm.

Table 1. Patient positioning and goniometer placement procedures

Parameter		Participant position	Fulcrum/axis	Fixed arm	Movable arm
Hip	Flexion	Supine	Greater trochanter of femur	Parallel to midaxillary line	Parallel to the lateral aspect of femur
	Extension	Prone			
	Abduction	Supine	Anterior superior iliac spine of the tested side	Along a line extending between the anterior superior iliac spines of both sides	Parallel to the anterior midline of femur on the tested side
	Adduction	Supine			
	Internal rotation	Sitting on edge of table with knee flexed 90°	Over patella	Along the anterior leg, vertical to the ground	Vertical to the ground
	External rotation				
Knee	Flexion/extension	Prone	Lateral knee articulation	Parallel to the lateral midline of femur	Parallel to the lateral aspect of fibula
Ankle	Dorsiflexion	Sitting on edge of table	Lateral malleolus	Parallel to fibula	Parallel to the lateral aspect of 5th metatarsal
	Plantar flexion				

Table 2. Mean (*SD*) and 95% CI of participants' demographic data and study outcomes for different body mass index categories

Parameter	Underweight (*n* = 52)	Normal (*n* = 117)	Overweight (*n* = 70)	Obese (*n* = 61)	*p* (ANOVA)
Age (years)	22.48 (3.8) (21.4–23.5)	22.21 (3.8) (21.5–22.9)	23.21 (3.4) (22.3–24.1)	23.38 (3.7) (22.4–24.3)	0.161
Weight (kg)	**52.03 (4.0) (50.9–53.1)**	**66.72 (3.3) 65.4–67.8)**	**73.72 (7.0) (72–75.4)**	**87.89 (9.3) 85.5–90.3)**	**< 0.001**
Height (m)	**1.71 (01) (1.6–1.7)**	**1.68 (0.1) (1.6–1.7)**	**1.68 (0.1) (1.6–1.7)**	**1.68 (0.1) (1.6–1.7)**	**0.013**
Body mass index	**17.71 (0.8) (17.5–17.9)**	**23.56 (1.1) (23.3–23.7)**	**26.17 (1.0) (25.9–26.4)**	**31.18 (1.3) (30.9–31.5)**	**< 0.001**
Hip flexion (°)	**125.5 (6.5) (123.7–127.3) **, *** **	**124.5 (7.9) (123.1–125.9) (a), (b)**	**121.2 (7.3) (119.4–122.9) (c)**	**114.9 (10.5) (112.2–117.6)**	**< 0.001**
Hip extension (°)	**20 (3.6) (18.9–21) **, *** **	**18.2 (4.9) (17.3–19.1) (b)**	**16.8 (4.2) (15.8–17.8)**	**15.8 (4.5) (14.7–16.9)**	**< 0.001**
Hip abduction (°)	42.4 (4.7) (41.1–43.7)	41.7 (5) (40.8–42.6)	41.9 (5.4) (40.6–43.2)	39.8 (7.8) (37.8–41.8)	0.072
Hip adduction (°)	28.1 (6.0) (26.4–29.8)	27.2 (4.8) (26.3–28)	27.9 (5.0) (26.7–29.1)	27.3 (5.3) (25.9–28.6)	0.624
Hip external rotation (°)	35.3 (3.7) (34.3–36.3)	36.8 (4.2) (36.0–37.5)	36.2 (4.4) (35.2–37.3)	36.8 (4.5) (35.6–37.9)	0.170
Hip internal rotation (°)	31.9 (5.4) (30.4–33.4)	32.2 (5.4) (31.2–33.2)	32.0 (5.8) (30.6–33.4)	31.2 (6.0) (29.6–32.7)	0.692
Knee flexion (°)	**138.3 (4.2) (137.1–139.5) *, **, *** **	**135.7 (5.1) (134.7–136.6) (b)**	**134.7 (5.6) (133.3–136.0)** (c)	**127.3 (2.9) (126.6–128.0)**	**< 0.001**
Ankle dorsiflexion (°)	**20.2 (4.0) (19.1–21.3) * **	**17.5 (4.8) (16.6–18.4)**	**19.2 (5.3) (18.0–20.5)**	**18.8 (4.8) (17.6–20.1)**	**0.005**
Ankle plantar flexion (°)	49.4 (7.2) (47.4–51.4)	48.3 (6.2) (47.1–49.4)	48.8 (8.6) (46.7–50.8)	47.2 (7.1) (45.3–49.0)	0.393

Bold indicates significant differences at $p < 0.05$.
* significant difference between underweight and normal, ** significant difference between underweight and overweight,
*** significant difference between underweight and obese, (a) significant difference between normal and overweight,
(b) significant difference between normal and obese, (c) significant difference between overweight and obese

Table 3. Mean (*SD*) and 95% CI of gender-based demographic data and study outcomes for different body mass index categories

Parameter	Gender	Underweight (*n*: 26M, 26F)	Normal (*n*: 57M, 60F)	Overweight (*n*: 36M, 34F)	Obese (*n*: 31M, 30F)	*p* (ANOVA)
Age (years)	Males	22.3 (4.5) (20.5–24.1)	22.4 (3.9) (21.4–23.5)	24.5 (3.7) (23.1–25.7)	24.9 (3.5) (23.6–26.2)	0.065
	Females	22.8 (3.2) (21.5–24.1)	21.9 (3.7) (21.1–22.9)	21.9 (3.7) (20.6–23.2)	21.8 (3.3) 20.5–23.0)	0.715
Weight (kg)	Males	**51.4 (3.1) (50.1–52.7) *, **, *** **	**70.0 (6.2) (68.4–71.7) (a), (b)**	**76.3 (7.8) (73.7–78.9) (c)**	**93.4 (8.2) (90.4–96.4)**	**< 0.001**
	Females	**52.7 (4.7) (50.8–54.6) *, **, *** **	**63.3 (4.8) (62.1–64.5) (a), (b)**	**71.0 (4.9) (69.3–72.7) (c)**	**82.2 (6.5) (79.7–84.6)**	**< 0.001**
Height (m)	Males	1.70 (0.1) (1.70–1.73)	1.72 (0.1) (1.70–1.74)	1.71 (0.1) (1.68–1.73)	1.73 (0.1) (1.70–1.75)	0.392
	Females	**1.73 (0.1) (1.70–1.76) *, **, *** **	**1.64 (0.1) (1.63–1.66)**	**1.64 (0.1) (1.63–1.66)**	**1.63 (0.1) (1.60–1.65)**	**< 0.001**

Body mass index	Males	**17.8 (0.6) (17.5–18.1) *, **, *****	**23.6 (1.2) (23.3–23.9) (a), (b)**	**26.1 (1) (25.8–26.4) (c)**	**31.3 (1.4) (30.8–31.8)**	**< 0.001**
	Females	**17.6 (0.7) (17.3–17.9) *, **, *****	**23.5 (1.1)** (23.2–23.7) (a), (b)	26.2 (1) (25.9–26.6) (c)	31.1 (1.2) (30.6–31.5)	< 0.001
Hip flexion (°)	Males	**121.3 (4.1) (119.6–122.9) *****	**120.5 (7.8) (118.4–122.5) (b)**	**120.6 (7.4) (118.2–123.1) (c)**	**113.3 (9.5) (109.8–116.8)**	**< 0.001**
	Females	**129.7 (5.8) (127.3–132.0) **, *****	**128.4 (5.9) (126.9–129.9) (a), (b)**	**121.7 (7.2) (119.2–124.2) (c)**	**116.6 (11.4) (112.3–120.9)**	**< 0.001**
Hip extension (°)	Males	**20.4 (3.5) (19.0–21.8) **, *****	**18.7 (5.6) (17.2–20.2) (a), (b)**	**14.7 (3.0) (13.7–15.7)**	**13.6 (3.0) (12.5–14.7)**	**< 0.001**
	Females	19.6 (3.8) (18.1–21.1)	17.8 (4.2) (16.7–18.9)	19.0 (4.1) (17.6–20.4)	18.1 (4.6) (16.4–19.8)	0.256
Hip abduction (°)	Males	**41.3 (3.4) (39.9–42.7) *****	**39.1 (4.4) (37.9–40.3) (b)**	**39.4 (4.8) (37.8–41.1) (c)**	**34.9 (5.1) (33.1–36.8)**	**< 0.001**
	Females	43.5 (5.6) (41.3–45.8)	44.1 (4.3) (43.0–45.3)	44.5 (4.7) (42.8-46.1)	44.8 (6.9) (42.2–47.4)	0.821
Hip adduction (°)	Males	28.3 (4.9) (26.3–30.3)	28.1 (5.4) (26.7–29.5)	28.3 (4.5) (26.8–29.9)	27.9 (5.9) (25.8–30.1)	0.992
	Females	27.9 (7.1) (25.1–30.8)	26.3 (3.9) (25.2–27.3)	27.5 (5.4) (25.6–29.3)	26.5 (4.7) (24.8–28.3)	0.462
Hip external rotation (°)	Males	34.9 (4.3) (33.1–36.7)	34.7 (4.6) (33.5–35.9)	34.7 (5.2) (32.9–36.5)	34.9 (5.0) (33.1–36.8)	0.993
	Females	35.7 (3.0) (34.5–36.9)	38.7 (2.5) (38.1–39.4)	37.8 (2.7) (36.9–38.7)	38.6 (2.9) (37.5–39.7)	< 0.072
Hip internal rotation (°)	Males	27 (2.5) (26.0–28.1)	27.2 (2.4) (26.5–27.8)	26.9 (2.9) (25.9–27.9)	25.8 (2.4) (24.9–26.6)	0.084
	Females	36.8 (1.8) (36.0–37.5)	37.0 (1.9) (36.6–37.5)	37.3 (2.2) (36.5–38.1)	36.7 (2.4) (35.9–37.6)	0.705
Knee flexion (°)	Males	**138.5 (3.6) (137.1–139.9) *, **, *****	**134.8 (5.7) (133.3–13.6.3) (b)**	**134.9 (6.5) (132.7–137.1) (c)**	**127.8 (2.9) (126.8–128.9)**	**< 0.001**
	Females	**138.1 (4.7) (136.2–140.0) **, *****	**136.4 (4.4) (135.3–137.6) (b)**	**134.4 (4.6) (132.8–136.0) (c)**	**126.8 (2.8) (125.7–127.8)**	**< 0.001**
Ankle dorsiflexion (°)	Males	**19.5 (3.8) (17.9–21.1) ***	**16.4 (4.9) (15.1–17.7)**	**18.8 (5.8) (16.8–20.8)**	**18.4 (4.9) (16.6–20.2)**	**0.032**
	Females	20.8 (4.0) (19.2–22.5)	18.5 (4.5) (17.4–19.7)	19.6 (4.7) (18.0–21.3)	19.3 (4.7) (17.5–21.0)	0.178
Ankle plantar flexion (°)	Males	48.2 (7.5) (45.1–51.2)	47.6 (6.1) (45.9–49.2)	46.9 (9.1) (43.8–50.1)	45.5 (6.4) (43.1–47.8)	0.497
	Females	50.6 (6.8) (47.8–53.3)	48.9 (6.3) (47.3–50.5)	50.7 (7.7) (48.0–53.4)	48.9 (7.5) (46.1–51.7)	0.523

Bold indicates significant differences at $p < 0.05$.
M – males, F – females
* significant difference between underweight and normal, ** significant difference between underweight and overweight,
*** significant difference between underweight and obese, (a) significant difference between normal and overweight,
(b) significant difference between normal and obese, (c) significant difference between overweight and obese

Table 4. Correlation coefficients between body mass index and hip, knee, and ankle joint range of motion goniometric measurements

Parameter	Body mass index (Spearman's rho)	*p*
Hip flexion	–0.344	< 0.001
Hip extension	–0.291	< 0.001
Hip abduction	–0.127	0.027
Hip adduction	–0.005	0.933
Hip external rotation	0.085	0.143
Hip internal rotation	–0.051	0.382
Knee flexion	–0.544	< 0.001
Ankle dorsiflexion	0.013	0.829
Ankle plantar flexion	–0.099	0.088

Bold indicates significant correlations at $p < 0.05$.

Table 5. Gender-based correlation coefficients between body mass index and hip, knee and ankle joint range of motion goniometric measurements

Parameter	Gender	Body mass index (Spearman's rho)	*p*
Hip flexion	Males	**–0.278**	**< 0.001**
	Females	**–0.443**	**< 0.001**
Hip extension	Males	**–0.542**	**< 0.001**
	Females	0.006	0.938
Hip abduction	Males	**–0.331**	**< 0.001**
	Females	0.058	0.477
Hip adduction	Males	–0.005	0.953
	Females	–0.019	0.821
Hip external rotation	Males	0.024	0.768
	Females	0.140	0.088
Hip internal rotation	Males	–0.169	0.083
	Females	0.082	0.319
Knee flexion	Males	**–0.497**	**< 0.001**
	Females	**–0.591**	**< 0.001**
Ankle dorsiflexion	Males	0.018	0.826
	Females	0.018	0.829
Ankle plantar flexion	Males	–0.164	0.064
	Females	–0.023	0.778

Bold indicates significant correlations at $p < 0.05$.

The results showed that hip and knee sagittal movements (flexion and extension), in addition to ankle dorsiflexion, were significantly different between the BMI categories. The underweight and normal subjects had the highest AROM measures, which were significantly different compared with the overweight and obese categories. A difference of 10.6°, 4.2°, and 11° was detected between the underweight and obese individuals for the hip flexion, hip extension, and knee flexion, respectively. Ankle dorsiflexion AROM for the normal category was significantly smaller than that for the underweight category by less than 3°, which is clinically trivial.

Table 3 depicts the results stratified by gender. The male-to-female ratio in each BMI category was nearly similar. Weight and BMI data were significantly different ($p < 0.001$) between the BMI categories for both genders. Only females in the underweight category were significantly taller than those in the remaining categories by about 10 cm. Hip and knee flexion movements were significantly and similarly different ($p <$ 0.001) between the BMI categories for the male and female subgroups. For both genders, a similar AROM pattern could be noticed, with the greatest AROM demonstrated by the underweight category, and the smallest for the obese category. For hip flexion, the difference between the underweight and obese categories was 8° and 13.1° for males and females, respectively. For knee flexion, the difference between the underweight and obese categories was 10.7° and 11.3° for males and females, respectively.

Only the male subgroup had significantly different measurements between the BMI categories for the hip extension ($p < 0.001$), hip abduction ($p < 0.001$), and ankle dorsiflexion ($p = 0.032$). While the difference between the highest and the lowest measured AROM was 6.8° and 6.4° for hip extension and abduction, respectively, it was only 3.1° for ankle dorsiflexion. Interestingly, the female group showed greater hip internal rotation than the male group by about 10°, across all BMI categories.

The statistical analysis revealed that the sagittal hip and knee, as well as hip abduction AROM were significantly negatively correlated with the participants' BMI, while the other hip and ankle joint movements were not (Table 4). The strongest significant negative correlation was the moderate one between knee sagittal AROM and BMI ($r = –0.544$, $p < 0.001$). Hip movements showed only weak significant negative correlations with BMI (Figure 1). Hip flexion ($r = –0.344$, $p < 0.001$) and extension ($r = –0.291$, $p < 0.001$) ROM presented only a weak significant correlation with BMI, with hip abduction ($r = –0.127$, $p = 0.027$) exhibiting the lowest significant correlation coefficient.

The assessment of the same correlation depending on gender demonstrated a similar correlation pattern in the male subgroup, but not among the females (Table 5). A weak-to-moderate negative correlation was found for hip flexion ($r =$ –0.278, $p < 0.001$), hip extension ($r = –0.542$, $p < 0.001$), hip abduction ($r = –0.331$, $p < 0.001$), and knee flexion ($r = –0.497$, $p < 0.001$) in the male subgroup. For the female subgroup, moderate negative correlations were observed for hip ($r =$ –0.443, $p < 0.001$) and knee ($r = –0.591$, $p < 0.001$) flexion only.

Discussion

The current study investigated the impact of BMI on the AROM of lower extremity joints. Both hip and knee flexion movements demonstrated statistically, as well as clinically significant differences between the groups (AROM was higher in the underweight and normal BMI populations). BMI exhibited a significant negative correlation primarily with sagittal plane movements as observed in the hip extension and abduction in males and hip flexion in both sexes in addition to knee flexion in both sexes.

Our findings agreed with several previous studies. Jeong et al. [28] found that passive knee and ankle ROM was significantly reduced if BMI increased. They proposed 2 reasons for their results. First, the accumulation of fat in different

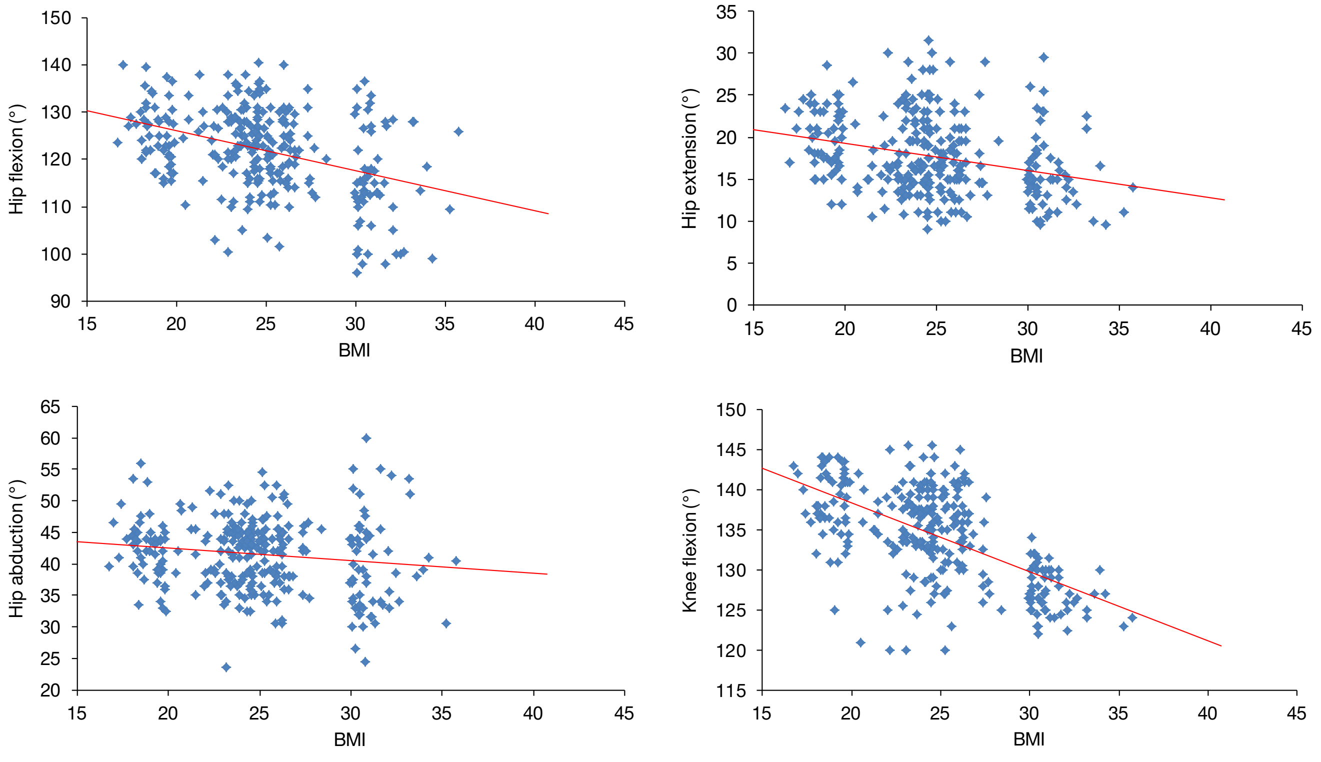

Figure 1. Significant correlations between body mass index (BMI) and hip and knee goniometric ROM measures

body regions may mechanically limit the movement. Second, subjects with high BMI tend to be less active and this attitude decreases the ROM a joint can perform.

Another study, conducted by Fairservice et al. [19], reported a moderate negative correlation between knee AROM and BMI in both active and sedentary persons. In this study, ROM was significantly lower in the sedentary group, which may support the second reason suggested by Jeong et al. [28] mentioned above. Moreover, knee flexion puts high stress on the joint and that is why the majority of the limitations in ROM seen by Fairservice et al. [19] were in flexion rather than extension.

In a third study, an elderly population with high BMI demonstrated restrictions in joint ROM. Lower knee ROM values were observed in subjects with high BMI either before or after total knee arthroplasty operations. According to the authors of this study, the results were attributed to the mechanical limitations caused by the accumulated fat behind the knees [29].

Regarding the current study, the negative correlation between BMI and sagittal plane movements of the hip and knee could be attributed to the changes in body composition. Fat may accumulate non-uniformly across different body regions with increased body weight. Persons with central obesity may demonstrate limited hip flexion due to early contact between the abdomen and thigh during hip flexion. Similarly, those having more lower extremity fat, commonly on the back of the thigh [13], may exhibit the same limitation during knee flexion [28, 30].

Unlike the proximal lower extremity joints, where the deposited fat is more likely to hinder ROM, the ankle region normally has less fat deposition. This increases the freedom of the ankle joint movements and significantly eliminates the movement-limiting effects of fat in this body part. Furthermore, the anatomical structure and biomechanical design of the ankle joint allow it to move freely through full ROM before any tissue contact takes place [30]. This could explain the lack of association between BMI and ankle joint AROM found in the current study. In contrast, another study reported that obese individuals had lower ankle plantar flexion ROM compared with normal ones. The authors attributed this finding to the effect of fat deposition around the bulky posterior ankle musculature [28].

Overweight and obesity have been associated with limited physical activity, which in turn may stimulate the accumulation of fibro-fatty connective tissue inside joints [30]. This phenomenon can result in decreased ROM and muscle strength [31]. Accordingly, moving a larger and heavier body part as the lower extremity could be a challenging task for obese people. To move the hip or knee joints, a person has to resist a great gravitational moment, particularly for sagittal and frontal plane movements, to lift the heavier and larger thigh and leg. The activity becomes even more cumbersome if one considers the long lever arm of the lower extremity during such movements. This can help explain the significant negative relationship between BMI and the sagittal plane movements of the hip and knee. Furthermore, this may also clarify the contradicting results obtained for the ankle joint movements and other transverse plane movements (hip rotation). The foot is a small body segment with a short lever arm to the centre of the ankle joint. Similarly, hip rotatory movements have a short lever arm compared with sagittal hip joint movements. Therefore, ankle joint and hip rotatory movements would not be burdensome for an obese person to perform through full ROM [16].

Patient positioning could also explain variability in joint ROM measurements [27]. Obese individuals may find it difficult to move a heavy body segment against gravity owing to the decline in physical abilities and decreased muscular performance [31]. During the measurement of sagittal hip movements, the participants lying in the supine position had to move the lower extremity against gravity to reach the maximum range. The foot has much less weight compared with other lower extremity segments. Therefore, measuring ankle joint movement in the antigravity position may have had a limited effect on ROM. Similarly, during hip rotation, the subjects had to move their legs, which have relatively low weight, against gravity. Therefore, the full hip rotation was not a challenging task for an obese person to perform [32].

Limitations

The current study encountered several limitations that have to be acknowledged. The sample sizes for different BMI categories were not matched; particularly, the normal BMI category had the largest number of participants. Despite its potential impact on the statistical output, this may be more representative of the real situation among the population. The World Health Organization has recently reported that around 30% of the population are overweight, 14% are obese, an even smaller percentage are underweight, and, consequently, the majority are under the normal BMI category, which nearly matches our study sample distribution [24].

Additionally, in the current study, we used a simple basic manual goniometer for ROM measurement, which limited the ability to evaluate non-planar movements as ankle inversion and eversion. Nevertheless, manual goniometry is a standard method applied in pragmatic daily clinical practice.

Conclusions

Sagittal hip and knee ROM is negatively correlated with BMI in healthy young adults. Thus, obese and overweight persons could likely present smaller hip and knee flexion/extension ROM values compared with their normal counterparts. Accordingly, obesity and overweight could be listed among the factors affecting sagittal hip and knee ROM, and clinicians should consider their patients' BMI when assessing lower extremity movements.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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