Muscle function, physical function, and gait in older women with and without knee osteoarthritis

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Abstract - Aim: To compare muscle function of knee extensors, gait parameters, and physical function in older women with and without knee osteoarthritis (KOA) and to associate these parameters to the KOA incidence in this population.

Methods: Sixteen older women with KOA (66.9 ± 5.5 years; 74.9 ± 10.0 kg; 157.9 ± 0.9 cm; 30.2 ± 5.0 kg/m²) and fourteen healthy counterparts (control group: CG; 68.8 ± 5.8 years; 68.9 ± 10.5 kg; 158 ± 0.06 cm; 27.4 ± 4.0 kg/m²) participated in this study. Muscle function, physical function, and gait parameters were evaluated in both groups. The Western Ontario and McMaster Index (WOMAC) questionnaire was answered only by the KOA group. A correlation was performed to verify if KOA incidence was associated with muscle function, physical function, and gait parameters.

Results: KOA group showed lower peak torque at 60°/s (30%; p = 0.003) and 180°/s (37%; p < 0.001), greater acceleration time at 60°/s (382%; p < 0.001), lower cadence (12.2%; p = 0.002), slower gait speed (19.5%; p < 0.001) and greater stride time (12.5%; p = 0.001) than CG group. However, there was no difference between groups in physical function (p < 0.0045). The KOA incidence presented a negative correlation with peak torque (rho = −0.602; p < 0.001), cadence (rho = −0.533; p = 0.002), gait speed (rho = −0.633; p < 0.001), stride length (rho = −0.517; p = 0.003) and a positive correlation with stride time (rho = 0.533; p = 0.002) and acceleration time (rho = 0.655; p < 0.001). Conclusion: Our findings suggest that knee osteoarthritis may impair the function of the knee extensors muscles and gait parameters. An association between the ability to produce force rapidly and gait speed with the KOA incidence in older women was also observed.

Keywords knee joint, mobility, older adults.

Introduction

The prevalence of knee osteoarthritis (KOA) increases with age, and it is the most common joint disease that causes mobility limitations1. Older women are more likely to develop KOA than men2, and decreased muscle quadriceps strength has been associated with increased pain, cartilage loss, and reduced physical function in this population compared to healthy age-matched controls3-5. Moreover, activation of the quadriceps muscles before the heel strike in walking may protect the musculoskeletal system and the knee joint6,7. Thus, quadriceps strength has been considered a primary risk factor for the progression of joint damage in persons with KOA8.

Activities of daily living, such as walking, climbing stairs, and rising from a chair demand muscle strength and the ability to develop force rapidly in a short period9,10. However, a muscle contractile velocity reduction is observed in older adults compared to younger individuals11-13. In addition, the decline in quadriceps muscle contractile velocity may occur before its strength reduction, deteriorating functional performance in the early stages of senescence14,15. Acceleration time, defined as “the time required to accelerate to a preset dynamometer speed,” provides valuable information regarding muscular capacity to produce maximal muscle action quickly16. It may be associated with the decline in the ability to perform activities of daily living. However, the changes in acceleration time in older adults with KOA are unknown. Besides the relevance of quadriceps strength and contractile velocity, gait speed is considered an essential parameter for keeping independence through life17. Gait speed is associated with survival in older adults, with significant increments per 0.1 m/s18. However, KOA incidence induces to nine times the high probability of having a faster decline in gait speed, approximately 2.5% per year19.

The older adults with KOA have shown a decrease in the knee extensors’ peak torque and acceleration time, lower physical function, and worse gait parameters than healthy older adults. Moreover, previous studies have shown a relationship between knee extensors muscle function, gait parameters, and decreased physical function in healthy older adults3,10,20. For example, knee extensor weakness may, to some extent, account for the difficulty and increased time required to stand from a seated position.
in older adults with KOA and mobility limitations\textsuperscript{21,22}. Hence, it is plausible to expect that older adults with KOA may present more significant impairment than healthy older adults, suggesting a negative impact on daily living activities\textsuperscript{23}. However, it is not clear in the literature if muscle function of knee extensors, physical function, and gait parameters are associated with the KOA occurrence in older adults\textsuperscript{8}.

Therefore, this study aimed to compare knee extensor muscle function, gait parameters, and physical function in older women with and without KOA and associate them with the KOA incidence in this population. We hypothesized that (I) the older women with KOA would present worse muscle function of knee extensors, gait parameters, and physical function than older women with no KOA; and (II) all these variables would be associated with KOA incidence.

**Methods**

**Study population and design**

Sixteen older women with KOA and fourteen healthy age and gender-matched control participants were eligible for this study. Exclusion criteria were the presence of prosthesis in the lower limbs, historical fracture in the lower limbs, use of the assistive device during walking, osteoarthritis of hip or ankle. The KOA participants were recruited from a hospital of the university and the community. The inclusion criteria were participants diagnosed with unilateral or bilateral knee osteoarthritis with radiological knee damage graded as I, II, and III according to the Kellgren-Lawrence scale\textsuperscript{24}. Participants with bilateral KOA, the more symptomatic limb was tested (e.g., pain, joint stiffness, and crepitation) by self-report since the similarity in lower extremity mechanics between unilateral and bilateral KOA is sufficiently robust to consider both subsets as a single cohort\textsuperscript{25}. Information on the pharmacological treatment of the participants with knee osteoarthritis was not obtained. Control participants were recruited only from the community, and the dominant limb was tested. The leg dominance was determined with the ball kick test, which consisted of asking the participants to kick a soccer ball with moderate intensity three times, and the leg used for most trials was considered as the dominant limb. The power of the study was calculated at post hoc considering: (i) one tail; (ii) normal parent distribution; (iii) 1.51 effect size $d$ from the difference between groups in the gait speed variable; (iv) maximum sampling error of 5%; (v) sample size KOA group; (vi) sample size CG group. The power obtained was 0.98. The Research Ethics Committee of the University approved the study (protocol number: 344.853). All participants signed an informed consent form to participate in the research and attended two days of testing, including the first-day physical characteristics assessment, 3D motion gait analysis, and the familiarization session of muscle function test. On the second day, participants performed muscle function and functional tests.

**Gait parameters analysis**

Kinematic data were conducted to determine the spatiotemporal gait parameters, such as cadence, velocity, stride length, and stride time. Gait assessment was performed on a level surface of 9 m longer in the laboratory's data collection area with a motion capturing system (Vicon®, Oxford, UK), consisting of ten T10 infrared optoelectronic cameras sampling at 100 Hz. The calibration was performed according to manufacturer recommendations and yielded a volume of 3 m long, 1.5 m wide, and 1.7 m in height. Data were collected using the Plug-in-gait sacrum model of lower limbs\textsuperscript{26}. Participants were encouraged to walk barefoot at a self-selected pace and performed a brief warm-up to accommodate initial variations in gait speed and ensure that participants were walking at their comfortable speed. Participants performed ten walking trials each, and spatiotemporal gait variables were calculated through the average of three first valid trials. The time series were normalized to 100% of total stride time using a spline function (Matlab R2009a\textsuperscript{(C)}, USA), considering two successive foot strikes of the more symptomatic limb in the KOA group and two successive foot strikes of the dominant limb in the control group.

**Muscle function of the knee extensors evaluation**

Peak torque was measured in the knee extensors using an isokinetic dynamometer (Biodex System 3; Biodex Medical Systems). Participants were positioned against the backrest of the stationary seat with a hip angle of $85^\circ$, and stabilizing belts were placed across the participant's chest and waist. The input shaft of the dynamometer was aligned with the axis of rotation of the participant's knee. The dynamometer was set in concentric mode at angular velocities of $60^\circ/s$ and $180^\circ/s$.

The older women performed three submaximal practice efforts before maximal trials. All participants received the same instructions for the test: “to perform the movement as faster and stronger as they could”. The test consisted of 3 repetitions at each angular velocity, with a rest period of 120 s between velocities\textsuperscript{27}. The greatest peak torque (N.m/kg) at $60^\circ/s$ and $180^\circ/s$ was calculated using a customized routine (Matlab R2009a\textsuperscript{(C)}, USA) and considered for data analysis. Acceleration time (ms) was determined as the lowest time to reach the peak torque among three trials through curves analyses by BIODEX software.

**Physical function**

All participants performed the short physical performance battery (SPPB), which consists of three tests: three
standing-balance trials to evaluate the static balance (tandem, semi-tandem, and side-by-side standing), five times sit to stand test to measure the lower limb strength (FTSST), and a 4-m walk to assess gait speed (4MWT). A score of 0 is the lowest level of physical function and 12 is the highest level of physical function \( 0.70 \), high \( 0.20 \); low \( 0.90 \), and very high \( 0.00 \). The level of significance of all tests after the Bonferroni correction was set at \( p < 0.0045 \). The software used for analysis was SPSS (version 20).

Western Ontario and McMaster Index (WOMAC)

The WOMAC osteoarthritis index is a valid and reliable tool for determining a disease-specific indicator of health status in KOA individuals \(^{34} \), which was translated and validated to the Portuguese language \(^{35} \). It provides information on related symptoms in three domains in patients with KOA \(^{33, 34} \), including a measure of pain (5 items), stiffness (2 items), and physical function (17 items), each item scored on a five-point Likert scale. Scores for each scale were calculated by summing the points of the individual items and higher scores represent worse health status.

Statistical analysis

Shapiro-Wilk test was applied and confirmed the data normality of anthropometric characteristics, peak torque, gait parameters, and physical function. Levene's test confirmed the homogeneity of the data. Anthropometric characteristics, peak torque, gait parameters, and physical function were compared between KOA and control groups applying the independent t-test. The Mann-Whitney U test was applied to compare acceleration time between groups. The effect size was determined based on Cohen's \( d \) calculation of unpaired comparisons \(^{36} \). The effect size values of references were: (> -0.20) trivial, (> 0.20) small, (> 0.50) moderate and (> 0.80) large effect. The WOMAC score was presented as mean and standard deviation only for the KOA group. The correlation between osteoarthritis and peak torque, acceleration time, gait parameters, and physical function was performed using Spearman's Rho test. The effect size values of references for the correlations were: negligible (0.00 to ± 0.20); low (± 0.21 to ± 0.40), moderate (± 0.41 to ± 0.70), high (± 0.71 to ± 0.90), and very high (± 0.91 to 1.00). The level of significance of all tests after the Bonferroni correction was set at \( p < 0.0045 \). The software used for analysis was SPSS (version 20).

Results

Participant's characteristics and descriptive statistics are presented in Table 1. There was no difference in anthropometric characteristics between groups (\( p > 0.0045 \)).

There was a significant difference in peak torque at 60°/s (\( t = -3.290 \); \( p = 0.003 \)) and at 180°/s (\( t = -3.713 \); \( p = 0.001 \)), in which CG presented greater peak torque at both velocities compared to KOA (60°/s: 30%; \( d = -1.20 \); 180°/s: 37%; \( d = -1.30 \)). In addition, there was difference in acceleration time at 60°/s (\( U = 28.500 \); \( p < 0.001 \)), in which KOA group presented greater acceleration time compared with CG (38%). However, there was no difference in acceleration time at 180°/s (\( U = 84.500 \); \( p = 0.243 \)) between groups. Results are shown on Figure 1.

All the participants were able to perform the physical function tests. There was no difference in the performance of SPBB (\( t = -2.171 \); \( p = 0.040 \)), TUG (\( t = 2.103 \); \( p = 0.046 \)) and 6MWT (\( t = -2.998 \); \( p = 0.006 \)) between groups. Physical function tests are presented in Figure 2.

There were differences between groups in cadence (\( t = -3.503 \); \( p = 0.002 \)), gait speed (\( t = -4.104 \); \( p < 0.001 \)) and stride time (t = 3.573; \( p = 0.001 \)), in which the KOA group presented lower cadence (12.2%; \( d = -1.28 \)) and gait speed (19.5%; \( d = -1.51 \)). In addition, KOA group showed a higher stride time (12.5%; \( d = 1.32 \)) compared to CG. There was no difference in stride length between

| Table 1 - Anthropometric characteristics, grade and WOMAC score from knee osteoarthritis and its matched-control group. |
|-----------------|----------|----------|-------|
| KOA  | CG      | N = 16   | N = 14 | p      |
| Age (years)    | 66.90 ± 5.50 | 68.80 ± 5.80 | 0.36   |
| Weight (kg)    | 74.90 ± 10.00 | 68.90 ± 10.50 | 0.12   |
| Height (m)     | 1.57 ± 0.09 | 1.58 ± 0.06 | 0.79   |
| BMI (kg/m²)    | 30.20 ± 5.00 | 27.40 ± 4.00 | 0.09   |
| Grade          |          |          |       |
| Grade I (n(%)) | 2 (12.50%) | –        | –      |
| Grade II (n(%))| 7 (43.75%) | –        | –      |
| Grade III (n(%))| 7 (43.75%) | –        | –      |
| Unilateral (n(%))| 9 (56.75%) | –        | –      |
| Bilateral (n(%))| 7 (43.75%) | –        | –      |
| WOMAC          |          |          |       |
| Pain (0-20 a.u.)| 8.40 ± 4.90 | –        | –      |
| Joint stiffness (0-8 a.u.)| 3.80 ± 1.80 | –        | –      |
| Physical function (0-68 a.u.)| 28.70 ± 15.00 | –        | –      |
| Total score (0-92 a.u.)| 40.10 ± 21.10 | –        | –      |

KOA: knee osteoarthritis group; CG: control group; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; BMI: body mass index.
groups ($t = -3.062; p = 0.005$). Results are presented in Table 2.

The correlation between the incidence of KOA, knee extensors muscle function, physical function, and gait parameters showed that lower cadence, gait speed, higher stride time, and higher acceleration time were significantly associated with KOA incidence. However, there were no correlations between the KOA incidence and peak torque at $60^\circ/s$ and physical function. These results are presented in Table 3.
Table 2 - Spatiotemporal gait parameters score from knee osteoarthritis and its matched-control group.

|                          | KOA           | CG            | p    |
|--------------------------|---------------|---------------|------|
| Cadence (steps/min)      | 107.50 ± 11.20| 122.50 ± 12.20| 0.002*|
| Gait speed (m/s)         | 0.99 ± 0.17   | 1.23 ± 0.14   | 0.001*|
| Stride time (s)          | 1.12 ± 0.11   | 0.98 ± 0.09   | 0.001*|
| Stride length (m)        | 1.10 ± 0.10   | 1.21 ± 0.08   | 0.005|

KOA: knee osteoarthritis group; CG: control group.

Table 3 - Correlation between KOA occurrence and muscle function, physical function, and gait parameters.

|                          | KOA           | p    |
|--------------------------|---------------|------|
| Peak torque 60°/s        | −0.471        |      |
| Peak torque 180°/s       | −0.602**      |      |
| Acceleration time 60°/s  | 0.655**       |      |
| Acceleration time 180°/s | 0.217         |      |
| SPPB                     | −0.361        |      |
| TUG                      | −0.187        |      |
| 6MWT                     | −0.486        |      |
| Cadence                  | −0.533*       |      |
| Gait speed               | −0.633*       |      |
| Stride time              | 0.533*        |      |

KOA: knee osteoarthritis; SPPB: short physical performance battery; TUG: timed-up and go test; 6MWT: 6-min walking test. *P < 0.05.

Discussion

The present study aimed to compare knee extensors muscle function, gait parameters, and physical function in older women with and without KOA, and the relationship of these parameters with the KOA incidence. The results showed that individuals with KOA presented lower peak torque, acceleration time, and a decline in gait parameters than their counterparts with no KOA. Moreover, only peak torque at 180°/s, acceleration time at 60°/s, and gait parameters were associated with KOA incidence.

Peak torque at both velocities differs between groups similar to previous studies. In addition, the reduction of the number and size of muscle fiber, especially in fast-twitch muscle fibers, in older adults with KOA compared to healthy counterparts was documented previously, which may explain the discrepancy of the results. In addition, only women participated in the present study, and women are more prone to present a greater decline in muscle function than men. Thus, older women with KOA show worse muscle function than healthy older women.

The physical function did not differ between the KOA group and CG, even though the scores of the KOA group of TUG and SPPB tests in the KOA group suggest poor balance and physical function. These results were not consistent with those observed in the acceleration time since the capacity to produce fast torque is strongly associated with functional performance. On the other hand, the lack of physical function difference between the groups may be explained by the self-reported good physical function observed in the WOMAC questionnaire for the participants with KOA. The KOA group also reported low pain and low joint stiffness, which may contribute to good performance on the functional tests. Moreover, the KOA group presented knee osteoarthritis in mild and moderate degrees, which may not yet have influenced physical function. Therefore, pain and joint stiffness may have an essential role in the physical function, while the decline in peak torque and worse acceleration time were not sufficient to decrease the physical function in older women with KOA. Despite both groups did not present physical function impairment, a previous study comparing groups of different muscle torque production levels (60°/s) identified knee extensor strength values associated with a high risk of developing severe mobility limitation. Older women who present less than 1.0 N.m/kg were considered at high risk of severe mobility limitation, even when they were initially well-functioning, while those with more than 1.34 Nm/kg were classified at low risk. Results between these scores represent a moderate risk to develop severe mobility limitation. Thus, the KOA and CG older women of the present study may be considered with a high and moderate risk of severe mobility limitation, respectively.

The performance in the gait parameters was worse in the KOA group than the CG. The lower cadence, gait speed, and the greater stride time in the KOA group may also be related to a more conservative walking pattern to decrease the knee joint load and probably by the fear of feeling pain during the activity. In the current study, the gait speed of the KOA group indicates that such older women are in the threshold of independence in daily activities (0.99 m/s) since older adults that walk at 1.0 m/s are considered physically functional, and speeds from 1.20 m/s show increased survival. Previous studies found higher self-selected gait speeds to older adults with KOA (graded as I, II, and III) between 1.09 and 1.27 m/s. The difference in gait speed between studies may be due to men's participation in the previous studies, while in the present study, men participation was documented previously.
study, only women were evaluated. Thus, older women with KOA showed less gait ability than CG, which may lead to dependence in daily living activities.

Another important finding of the present study was the correlation of peak torque at 180°/s, acceleration time, and gait parameters with the KOA occurrence. The decline in the capacity to develop force rapidly has been associated with the worse performance in daily living activities9,10. Our results showed that this decline is more pronounced in older women with KOA than in healthy older women. Gait parameters are also related to independence in daily activities. This finding is relevant because spatiotemporal gait parameters are relatively simple measures and may be used even in a clinical context. Therefore, peak torque, acceleration time, and gait parameters may be considered as possible predictors of KOA and may contribute to identifying older women at risk to develop KOA.

The participation of only older women in the present study limits the generalization of the results to other populations (e.g., older men). On the other hand, older women are more prone to develop KOA than men11. There was no control over the pharmacological treatment of participants with KOA. However, all participants were able to perform all tests, and, probably, the possible pharmacological treatment did not influence the results in the study. Additionally, the low number of participants made it impossible to carry out a logistic regression to verify whether peak torque, acceleration time, and gait parameters can be predictors of the KOA incidence.

Conclusion

Our findings suggest that KOA may impair the function of the extensors muscles and gait parameters. Moreover, the association between the ability to produce force rapidly and gait speed with the KOA incidence in older women was observed. Experimental studies are required to confirm if the improvements in these parameters can predict, prevent or reduce KOA progression.

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