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ORIGINAL ARTICLE

Identifying recreational physical activities associated with muscle quality in men and women aged 50 years and over

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Abstract
Background Several studies conducted in a laboratory-related environment have shown that exercise is associated with increased muscle quality in older adults. The aim of the present study was to investigate whether recreational exercise may also be associated with muscle quality in men and women aged 50 years and over.
Methods Data are from 312 individuals (215 women) aged 50 years and older. Body composition (dual-energy X-ray absorptiometry) and knee extension strength (KES) of the right leg (one repetition maximum) were assessed. Muscle quality (MQ) (KES/right lower limb lean mass) was calculated. Recreational exercises (duration and weekly amount) were determined by structured interview.
Results The duration of the period during which participants practiced resistance activities was the only predictor of MQ ($p = 0.018$) and explained an additional 1.6 % of the variance in MQ, after controlling for age and gender. Furthermore, the weekly amount of practice of aerobic activities significantly interacted with age ($p < 0.001$) to determine MQ.
Conclusions Findings suggest that long-term engagement in resistance exercise is beneficial for muscle quality and should be encouraged. Furthermore, beyond 60 years, aerobic activities also seem to be positively associated with muscle quality.

Keywords Resistance training · Recreational exercise · Muscle mass · Muscle strength · Physical activity

1 Introduction

A number of studies investigated the relationship between muscle quality (MQ) (strength per unit of muscle) and physical function, some showing positive correlations [1-4], while others do not [5, 6]. In an attempt to clarify these findings, we showed that this relationship was complex and influenced by at least three factors: lean body mass, the degree of obesity (as assessed by body mass index (BMI)), and age [7]. These results highlighted that it was important to preserve MQ with increasing age and BMI in order to maintain functional capacity. Therefore, preventing the negative effects of age on MQ [8, 9] can only benefit older adults. It is not clear when the decline in muscle quality really becomes significant, but previous studies show that the loss of muscle mass and strength (i.e., the two components of muscle quality) is already evident at the fifth decade and then becomes even more pronounced [10, 11].

The strategy most commonly used to improve MQ in elderly is exercise, especially resistance training [12-15]. Nine to 14 weeks of resistance training have been reported to improve MQ by 14 to 28 % in both men and women [12-15]. In addition, Kennis et al. [16] observed that 1-year fitness or vibration trainings enhanced MQ (+11 and +7 %, respectively). Chastin et al. [17] also reported that alternating periods of intense activity and long recovery times were associated with MQ in men.

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With the exception of the work of Chastin et al. [17], all interventions mentioned above [12-16] were conducted in the context of laboratory-related exercise programs. These programs were designed to be reproducible and effective, that is, of a sufficient level of difficulty to maximize the probability of observing significant effects, while limiting the choice of practice, attendance, repetition, intensity, etc. However, outside of this ideal context, exercises can be quite different. It is recognized that elderly individuals are very sensitive to factors that may hamper their involvement in exercise. Eighty-seven percent of them have at least one barrier to prohibit exercise participation [18]. Fears of incurring injury or pain, exacerbation of illness or disease, questions over the expected benefits of exercise, or being “too old” are frequently cited reasons for not engaging in exercise [19]. Even among those engaged in exercise, only 30 % of older men and 15 % of older women actually sustain regular activities [20]. Therefore, it is legitimate to question the actual benefits of exercise in these conditions. Consequently, the aim of the present analysis was to investigate the relationship between recreational exercise and muscle quality in men and women aged 50 years and older.

2 Methods

2.1 Study population and procedure

Five hundred and twenty-five registered members of the YMCAs of Montreal (164 men and 361 women) aged 50 years and over (50–89 years) volunteered to participate in this study. The minimum age was set at 50 since the decline in muscle function becomes apparent at this age [10, 11]. To be included in the study, participants had to (a) be registered at the YMCA, (b) live and get around autonomously in the community, and (c) be able to understand and answer the questionnaires. Participants were excluded if used walking aid. All procedures were approved by the ethics committee of the University of Quebec at Montreal. All participants were fully informed about the nature, goal, procedures, and risks of the study, and they gave their informed consent.

After screening for the aforementioned inclusion criteria, participants were invited to visit their YMCA center where their muscle strength and physical function were assessed. They were then invited for a visit at the University of Quebec at Montreal where their body composition was assessed using dual-energy X-ray absorptiometry (DXA). Two hundred participants chose not to take the DXA and were excluded from these analyses. Thirteen additional participants were excluded because of missing data on muscle strength assessment. The present analyses were limited to the 312 (97 men and 215 women) remaining participants.

2.2 Anthropometric measurement and body composition assessment

Body weight (BW) was measured using an electronic scale (Tanita BC-558, Tanita, Arlington Heights, IL). Height was measured using a stadiometer (Seca, Hanover, MD) attached to the wall. Body mass index [BMI = BW (kg)/height (m^2)] was calculated. Lean body mass (LBM) was evaluated by DXA (version 6.10.019; General Electric Lunar Corporation, Madison, WI). Appendicular lean body mass (AppLBM) [sum of upper and lower limb lean body masses (in kg)] and appendicular lean body mass index [AppLBMI = AppLBM (kg)/height^2 (m^2)] were calculated.

2.3 Muscle quality calculation

Lower limb MQ was calculated in three steps, as described elsewhere [7]: in step 1, the maximum KES of the participants’ right leg was determined by one repetition maximum (RM) on a standard Atlantis C-105 knee extension machine (in kg) and multiplied by 9.81 to be expressed in Newton (N); in step 2, the right lower limb LBM was evaluated by DXA; and in step 3, muscle quality was finally calculated by dividing KES of the right leg by right lower limb LBM (in N/kg LBM).

2.4 Exercise habits

Recreational exercise habits (planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness) have been identified using structured interview conducted by a trained kinesiologist using a form comprising activities available at the YMCAs and blank spaces to allow recording of unlisted activities. This assessment method was chosen over more objective methods (e.g., accelerometry) because (1) it allows to cover and identify all exercises (e.g., resistance training, walking, swimming, martial arts, yoga, etc.), (2) it allows to collect accurate information for each activity, and (3) it is clinically very accessible.

Participants were asked to specify the exercise time (in min/week) for each activity in which they were currently engaged, either inside or outside the YMCAs, and for how long these activities have been practiced (in months). Activities were then categorized in three main categories: resistance, aerobic, and body and mind exercises. Based on this information, we calculated the weekly exercise time (WET) as well as the average exercise duration (AED) in total or by category of activity.

2.5 Potential confounders

Physical examination and health status questionnaires were used to record comorbid conditions (hypertension, diabetes, cancer, stroke, or other diseases). Cognitive impairment was assessed with the Montreal Cognitive Assessment (MoCA) questionnaire, and a score less than 26 was considered low [21]. Sociodemographic information (level of education, smoking habits, etc.) was also noted.

2.6 Statistical analysis

Hierarchical multiple regression analysis was used to analyze the association between exercise characteristics and MQ. Bivariate tests were first conducted to determine which variable to include in the regression analysis. Gender (t=−5.480, p<0.001) and age (t=−0.329, p<0.001), but not BMI, were associated with MQ and considered as a control variables. Among the exercise characteristics (total, resistance, aerobic, and body and mind WET or AED), only resistance AED was associated with MQ (r=0.179, p=0.003). No comorbidity (present or past cancer, cardiovascular disease, hypertension, arthritis, back pain, and cognition) was associated with MQ. In spite of gender differences in MQ, there was no evidence that the association between exercise characteristics and MQ differed by gender (p values from gender interaction tests were 0.05). We thus decided not to conduct sex-stratified analysis.

Preliminary analyses were conducted to ensure that the assumptions of normality, linearity, multicollinearity, and homoscedasticity were not violated. Hierarchical regressions were also used to investigate the relationship between resistance AED, right leg KES, and LBM. We then tested the hypothesis that age may interact with other physical activity characteristics (total or categorical WET or AED). To do so, following the method of Aiken and West [22], variables [age and exercise characteristics (total or categorical WET or AED)] were centered at the mean and entered in regression analyses (as well as their interaction term). Analyses were performed using SPSS 17.0 (Chicago, IL). A p value less than 0.05 was considered statistically significant.

3 Results

3.1 Participant's characteristics

Participant's characteristics are presented in Table 1. Briefly, body weight, BMI, AppLBMI, right lower limb LBM, KES, and MQ were higher in men than in women (p<0.001). Body and mind AED was also higher in men than in women (p=0.030). The reason why a disproportionate number of women volunteered to participate in the study is not obvious, but one may hypothesize that it may originate from gender differences in exercise motivation and expectation in terms of physical health, so that the topic of this study (physical activity, body composition, and physical function) is closer to women's concerns. As for example, women appear to be more likely than men to report falls, seek medical care, and/or discuss falls and fall prevention with health-care provider [23].

3.2 Relationship between exercise and muscle quality

Age and gender were entered at step 1, explaining 20 % of the variance in MQ. After entry of resistance AED at step 2, the total variance explained by the model as a whole was 21.6 %, F(3, 308) = 25.410, p<0.001. Resistance AED explained an additional 1.6 % of the variance in MQ, after controlling for age and gender (r^2 change = 0.016, F change (1, 308)=5.677, p=0.018). In the final model, resistance AED (standardized β =0.128; p=0.018), age (standardized β=−0.312; p<0.001), and gender (standardized β=0.287; p<0.001) predicted MQ. The relationship between resistance AED and MQ is illustrated in Fig. 1a.

3.3 Relationship between exercise, knee extension strength, and lean body mass

First, age and gender were entered at step 1, explaining 44.6 % of the variance in KES. After entry of resistance AED at step 2, the total variance explained by the model as a whole was 46 %, F(3, 308) = 96.649, p<0.001. Resistance AED explained an additional 1.7 % of the variance in KES, after controlling for age and gender (r^2 change = 0.017, F change (1, 308) = 8.773, p=0.003). In the final model, resistance AED (standardized β=0.132; p=0.003), age (standardized β =−0.324; p<0.001), and gender (standardized β=0.542; p<0.001) predicted KES.

Finally, age and gender were entered at step 1, explaining 64.2 % of the variance in LBM. After entry of resistance AED at step 2, the total variance explained by the model as a whole was 64.4 %, F(3, 308) = 185.364, p<0.001. Resistance AED explained an additional 0.1 % of the variance in LBM, after controlling for age and gender (r^2 change = 0.001, F change (1, 308) = 1.140, p=0.286). In the final model, age (standardized β=−0.233; p<0.001) and gender (standardized β=0.756; p<0.001), but not resistance AED (standardized β=0.037; p=0.286), predicted LBM. The relationship between right lower limb KES and LBM with resistance AED is illustrated in Fig. 1b.

3.4 Influence of age in the relationship between exercise and muscle quality

Age did not interact with resistance AED to determine MQ (standardized β=0.035; p=0.512). Results of the

Table 1 Participants' characteristics

Variable	Men (n=97)	Women (n=215)	p
Age	61±8	61±2	0.68
Anthropometric measures			
Body weight (kg)	81.4±15.2	66.8±11.5	<0.001
BMI (kg/m^2)	27.0±4.2	25.7±4.4	0.024
Muscle mass and function			
AppLBMI (kg/m^2)	9.2±0.9	7.3±0.8	<0.001
Right leg LBM (kg)	10.4±1.5	7.3±1.1	<0.001
KES (N)	340±130	177±98	<0.001
Muscle quality (N/kg)	32±12	24±13	<0.001
Exercise characteristics[a]			
Physically active (%)	99.0	97.7	0.44
Total WET (min/week)	522±332	499±278	0.52
Total AED (months)	118±102	90±78	0.021
Practicing resistance activities (%)	68.0	63.3	0.41
Resistance WET (min/week)	128±83	109±71	0.090
Resistance AED (months)	81±108	52±83	0.060
Practicing aerobic activities (%)	99.0	95.3	0.11
Aerobic WET (min/week)	394±283	378±261	0.62
Aerobic AED (months)	137±122	113±113	0.09
Practicing body and mind activities (%)	32.0	43.3	0.059
Body and mind WET (min/week)	123±120	135±82	0.62
Body and mind AED (months)	90±116	42±52	0.030
Smoking habits (%)			
Current smoking	7.4	6.0	0.82
Past smoking	60.9	62.6	0.91
Education level (%)			
Primary school	3.1	5.1	0.72
High school	9.3	9.3	
Postgraduate degree	87.6	85.5	
Comorbidities (%)			
Present or past cancer	2.1	14.9	<0.001
Cardiovascular disease	17.7	12.9	0.29
Hypertension	26.3	20.5	0.30
Arthritis	41.7	48.4	0.33
Back pain	29.9	26.5	0.59
Cognitive impairment	17.9	11.0	0.10

BMI body mass index, *AppLBMI* appendicular lean body mass index, *LBM* lean body mass, *KES* knee extension strength, *WET* weekly exercise time, *AED* average exercise duration

[a] Descriptive analyses were conducted in individuals practicing the physical activity in question

inter-relationship between age, exercise, and muscle quality are illustrated in Fig. 2a, b. Among the other exercise characteristics, only total WET (standardized β=0.107; p=0.046) and aerobic WET (standardized β =−0.313; p<0.001) significantly interacted with age to determine MQ. The relationship between total WET and aerobic WET with MQ for predefined ages is illustrated in Fig. 3a–c. Figure 4a, b also illustrated the relationship between age and MQ for predefined levels of total WET and aerobic WET, respectively.

4 Discussion

Several studies conducted in a laboratory-related environment have shown that exercise programs, particularly resistance training programs, had positive effects on MQ in older adults [12-15]. However, it is reasonable to question whether recreational exercise may lead to similar results.

The major finding is that resistance AED was the only factor that appears to influence muscle quality in both men and women (Fig. 1a), suggesting that practicing recreational

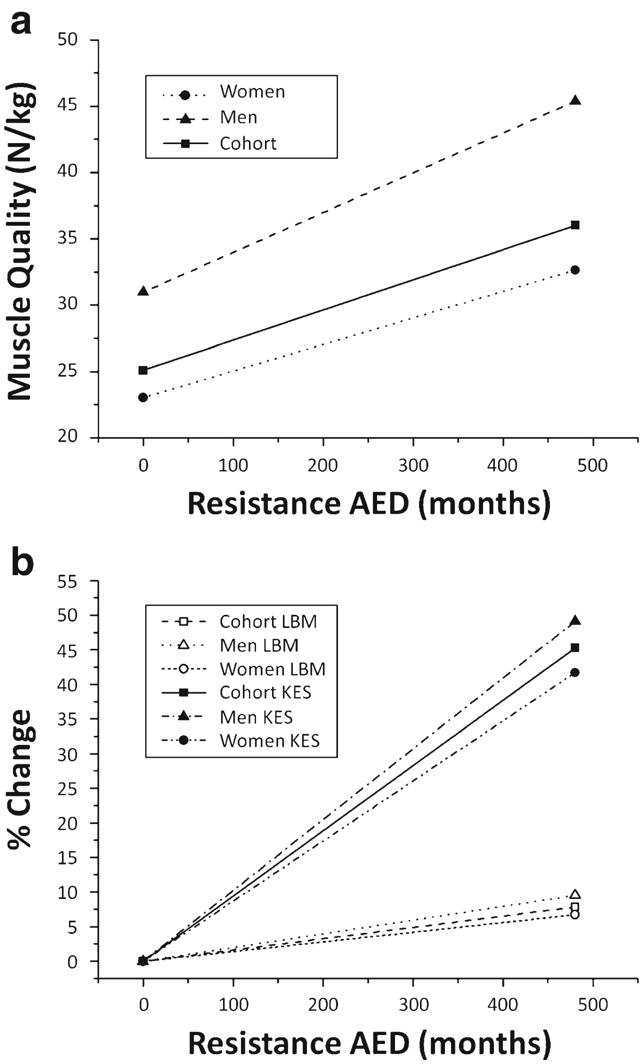


Fig. 1 Relationship between muscle mass and function with resistance AED. Curves are extrapolated from regression analyses. A maximum of 480 months was chosen to properly represent the full range of resistance AED observed in the cohort. **a** Relationship between muscle quality and resistance AED. Resistance AED was first included in the regression as a single predictor to generate the cohort curve. Gender and its interaction term with resistance AED were then added in the regression to generate men and women curves. **b** Relationship between lean body mass, muscle strength, and resistance AED. Resistance AED was first included in the regression as a single independent variable to predict right leg LBM and to generate the cohort curve. Gender and its interaction term with resistance AED were then added in the regression to generate men and women curves. Cohort, men, and women KES curves were extrapolated according to the same process. LBM and KES values are expressed in percentage of the values obtained for resistance AED = 0. Theoretical cohort, men, and women KES values for resistance AED = 0 were 212, 323, and 173 N, respectively. Theoretical cohort, men, and women LBM values for resistance AED = 0 were 8.1, 10.3, and 7.3 kg, respectively. *AED* average exercise duration, *LBM* lean body mass, *KES* knee extension strength

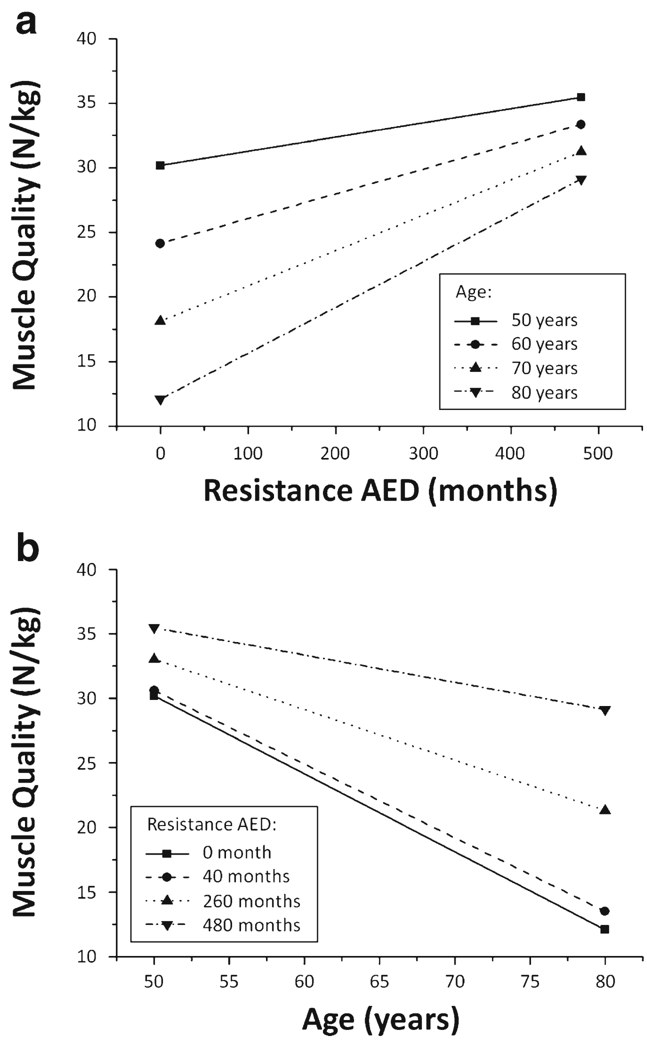
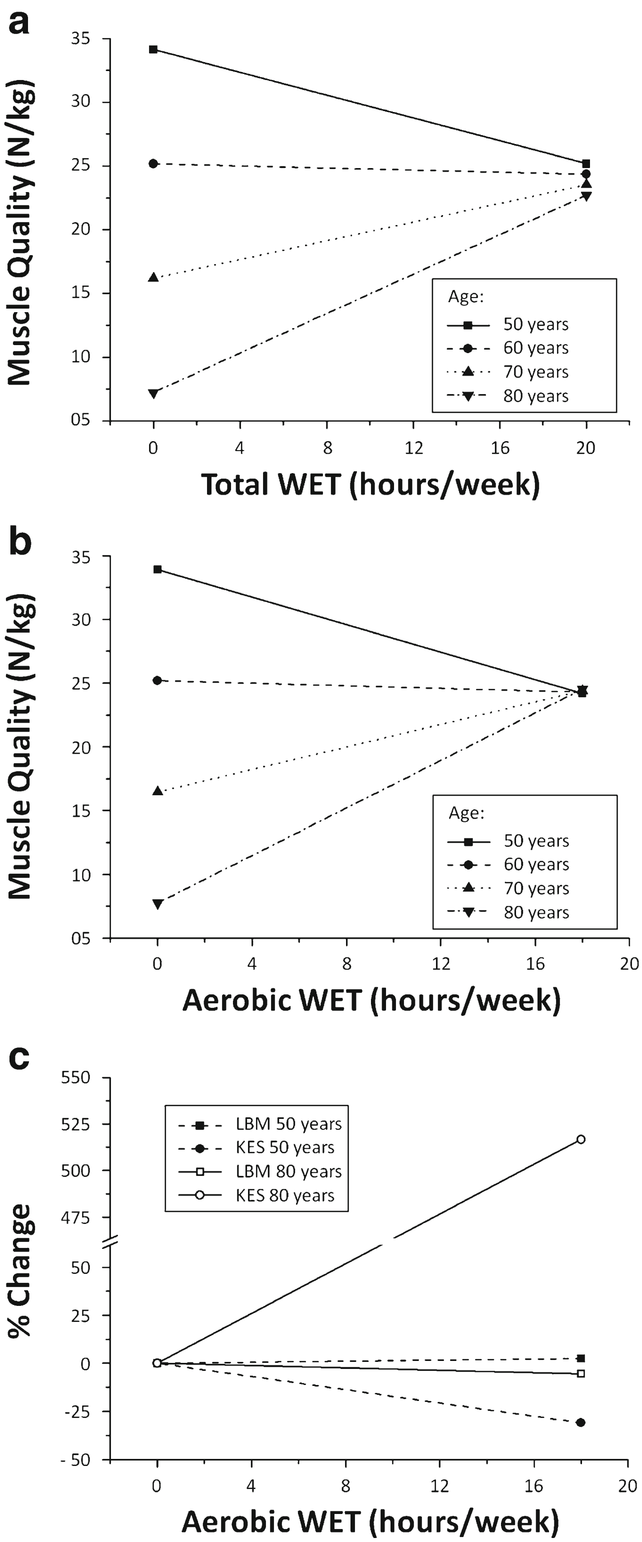


Fig. 2 Relationship between resistance AED, age, and muscle quality. **a** Relationship between resistance AED and muscle quality for predefined ages. A maximum of 480 months was chosen to properly represent the full range of resistance AED observed in the cohort. **b** Relationship between age and muscle quality for predefined levels of resistance AED. A resistance AED of 40 months is close to the average level of the entire cohort (39.8 months). *AED* average exercise duration

resistance activities for a long period of time would be more important and beneficial than large amounts of varied exercises per week. When considering the cohort as a whole, resistance AED explained 1.6 % of the variance in MQ after accounting for age and gender (which explained 20 % of its variance). However, this result should be qualified since, as discussed below, age significantly influenced this relationship.

Furthermore, since muscle quality depends on both muscle mass and strength, the relationship between resistance AED and MQ may be interpreted cautiously. As illustrated in Fig. 1b, it is noteworthy that the positive association between resistance AED and MQ mainly results from a positive association between resistance AED and muscle strength. Yet, these results seem to support the recommendations for physical activity as well as the public health discourse, which state that it is beneficial to adopt a healthy lifestyle at early age and maintain it throughout the entire life to obtain benefits at older ages [24]. That is, although cross-sectional, the analyses presented here strongly suggest that lifelong exercise is beneficial



◀ **Fig. 3** Relationship between total and aerobic WET with muscle quality, lean body mass, and muscle strength according to age. **a** Relationship between total WET and muscle quality according to age. A maximum of 20 h was chosen to properly represent the full range of total WET observed in the cohort. **b** Relationship between aerobic WET and muscle quality according to age. A maximum of 18 h was chosen to properly represent the full range of aerobic WET observed in the cohort. **c** Relationship between lean body mass, muscle strength, and aerobic WET according to age. Curves are extrapolated from regression analyses in which the following were included (1) age, LBM, and their interaction term or (2) age, KES, and their interaction term. LBM and KES values are expressed in percentage of the values obtained for aerobic WET = 0. Theoretical 50- and 80-year-old individuals LBM values for aerobic WET = 0 were 7.9 and 6.3 kg, respectively. Theoretical 50- and 80-year-old individuals KES values for aerobic WET = 0 were 274 and 23 N, respectively. *WET* weekly exercise time, *LBM* lean body mass, *KES* knee extension strength

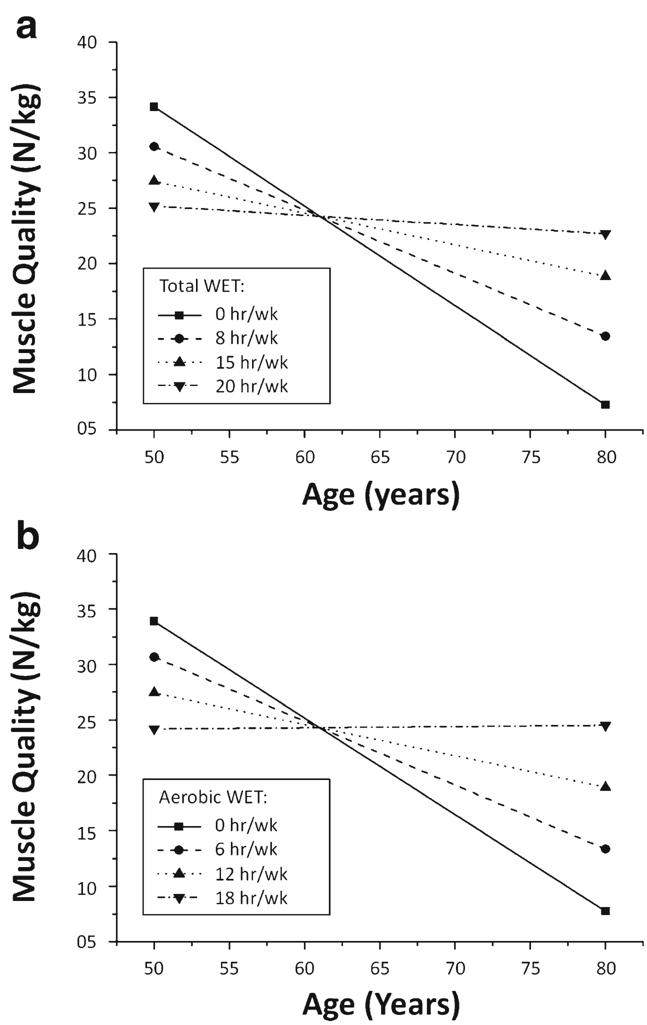


Fig. 4 Relationship between age and muscle quality according to total or aerobic WET. **a** Relationship between age and muscle quality according to total WET. A total WET of 8 h is close to the average level of the entire cohort (8.3 h). **b** Relationship between age and muscle quality according to aerobic WET. An aerobic WET of 6 h is close to the average level of the entire cohort (6.2 h). *WET* weekly exercise time

for muscle function. Muscle unit survival in active elderly may be one of the factors contributing to such benefits [25].

In a recent meta-analysis, Peterson et al. [26] reported that KES increased by 33 % for a mean training duration of 18 weeks (in a laboratory-related environment) in older adults aged 50–92 years. By way of comparison, according to our results (Fig. 1b), a similar duration would be associated with strength changes of 2 %. A theoretical resistance AED of 350 months (≈29 years) would be necessary to achieve strength increases of 33 % (Note that only eight participants have exercised for that long).

Obviously, given the cross-sectional design of the present study, comparisons with the meta-analysis of Peterson et al. [26] must be examined cautiously. However, they may highlight some differences between laboratory-related and recreational exercises that could, at least partially, be attributable to differences in constraints and coaching existing between these environments. As observed by Deforche and De Bourdeaudhuij [27], while no differences were found in perceived barriers and benefits to exercise, older adults involved in supervised exercise programs had higher levels of activity and reported higher self-efficacy compared to active older adults that are not engaged in supervised exercise programs. These authors hypothesized that participation was based on their willingness to participate in a structured program, which in turn increased once more their perceptions of exercise capabilities [27]. Furthermore, there is evidence that being involved in specific programs for seniors, with instructions on how to exercise safely and with opportunities for regularly supervised activity is of importance for elderly [28]. Results of the present study suggest that the presence of a supervisor is necessary, not only for safety but also to ensure the effect of training.

The second part of the analysis dealt with the influence of age in the relationship between recreational exercises and MQ. First, it is interesting to note that age has a little influence on the relationship between resistance AED and MQ. Resistance AED was positively associated with MQ across all age groups. Furthermore, as depicted in Fig. 2a, an 80-year-old individual who have practiced resistance training exercises for 40 years would theoretically have a MQ of 2.5 times higher than that of an individual with the same age who did not train in resistance (29 and 12 N/kg, respectively). This MQ value (29 N/kg) is almost identical to the MQ of a 50-year-old individual who did not train in resistance (30 N/kg).

While bivariate tests identified resistance AED as the only predictor of MQ, interaction analyses revealed that depending on age, aerobic WET may also be taken into account (Fig. 3b). Since aerobic WET represents on average 72 % of total WET (data not shown), it is not surprising that total WET (all activities combined) also interacted with age (Fig. 3a). While aerobic WET was negatively associated with MQ in 50-year-old individuals, it was positively associated with MQ in 80-year-old participants (the transitional age being around 60 years), suggesting that aerobic training may not be overlooked in older adults. However, theoretical curves representing mean total or aerobic WET (8 and 6 h, respectively; Fig. 4) show that muscle quality is reduced by half between 50 and 80 years, although such amounts of practice are broadly superior to the recommendations of the 2011 American College of Sports Medicine (ACSM) Position Stand [24]. This suggests that recreational aerobic activities are not the preferred type of activity to maintain or increase muscle quality.

Figure 3c provides us with an explanation concerning this age-dependent relationship between aerobic WET and muscle quality. In both 50- and 80-year-old individuals, muscle mass appears to remain relatively constant, regardless of aerobic WET. However, while aerobic WET was negatively associated with muscle strength in 50-year-old individuals, it was positively associated with muscle strength in 80-year-old individuals. Yet, even the theoretical fivefold increase of the basal KES value of 80-year-old individuals who train for 18 h/week does not reach the mean KES value of a sedentary 50-year-old individual (140 vs. 270 N; see the legend in Fig. 3c).

In summary, we observed that recreational resistance AED and aerobic activities beyond 60 years were associated with MQ. It should, however, be kept in mind that other factors, such as nutrition, may be of importance. For instance, in obese individuals, the combination of diet and exercise was even more effective than exercise or diet alone to improve MQ [29, 30].

A number of limitations need to be considered. The cross-sectional design of the study does not allow us to draw conclusions as to causal associations between physical exercise, age, and muscle quality. Furthermore, physical activity was evaluated by interview, which may decrease the risk of recall bias, but increase the risk of social desirability bias. Finally, although we have statistically ensured that there was no gender interaction, it remains possible that a disproportionate number of women have influenced the results. However, the use of questionnaire allowed us to cover and identify all physical activities. The use of accurate devices to evaluate body composition and muscle quality also reinforces our findings.

5 Conclusion

In conclusion, our results suggest that long-term engagement in recreational exercise, especially resistance exercise, is beneficial for muscle quality and should be encouraged across all age groups. Furthermore, beyond 60 years, the duration of weekly aerobic activities also seems to be positively associated with muscle quality.

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Conflict of interest Sébastien Barbat-Artigas, Sophie Dupontgand, Charlotte H. Pion, Yannick Feiter-Murphy, and Mylène Aubertin-Leheudre declare that they have no conflict of interest.

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