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Low- and High-Resistance Exercise: Long-Term Adherence and Motivation among Older Adults

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Key Words
Sarcopenia · Elderly people · Resistance exercise · Training load · Motivation · Exercise barriers

Abstract
Background: In terms of motivation and long-term adherence, low-resistance exercise might be more suitable for older adults than high-resistance exercise. However, more data are needed to support this claim. ***Objective:*** The objective was to investigate the effect of low- and high-resistance exercise protocols on long-term adherence and motivation. ***Methods:*** This study was designed as an exploratory 24-week follow-up of a randomized 12-week resistance training intervention in older adults. Participants were free to decide whether or not they continued resistance training at their own expense following the intervention. Fifty-six older adults were randomly assigned to HIGH [2 × 10–15 repetitions at 80% of one repetition maximum (1RM)], LOW (1 × 80–100 repetitions at 20% of 1RM), or LOW+ (1 × 60 repetitions at 20% of 1RM + 1 × 10–20 repetitions at 40% 1RM). Motivation, self-efficacy and the perceived barriers for continuing resistance exercise were measured after cessation of each supervised intervention and at follow-up, while long-term adherence was probed retrospectively at follow-up. ***Results:*** Participants reported high levels of self-determined motivation before, during, and after the supervised intervention, with no differences between groups ($p > 0.05$). Nevertheless, only few participants continued strength training after the intervention: 17% in HIGH, 21% in LOW+, and 11% in LOW ($p > 0.05$). The most commonly reported barriers for continuing resistance exercise were perceived lack of time (46%), being more interested in other physical activities (40%), seasonal reasons (40%), and financial cost (28%). ***Conclusion:*** The results suggest no difference in long-term adherence after the end of a supervised exercise intervention at high or low external resistances. Long-term adherence was limited despite high levels of self-determined motivation during the interventions. These findings highlight the importance of further research on developing strategies to overcome barriers of older adults to adhere to resistance exercise without supervision.

Introduction

Sarcopenia, i.e. the age-related loss in muscle mass and muscle function, can have a deteriorating effect on functional performance [1, 2]. Resistance training has been

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proposed as a potential strategy for counteracting sarcopenia in older adults. Moderate to high external resistance exercises [60–85% of the one repetition maximum (1RM)] are currently recommended for obtaining optimal effects [3]. However, to minimize potential risks for injury, alternative low-resistance exercise protocols have been introduced in the literature.

There is considerable evidence that both high- and low-resistance exercise regimens can be safe and equally effective to induce hypertrophy and strength gains in older adults [4, 5]. However, virtually no studies have addressed the issues of motivation and (long-term) adherence, even though these issues are as important as the safety and effectiveness of training protocols. Simply put, if only few older adults are motivated to engage in resistance exercise, its public health relevance might be questioned.

According to the Self-Determination Theory, different types of motivation regulate an individual's behavior [6]. These types of motivation can be situated on a self-determination continuum, ranging from controlled forms of motivation [i.e. external regulation ('I exercise because my doctor told me so') and introjected regulation ('I exercise because I would feel guilty if I would not')] to autonomous forms of motivation [i.e. identified regulation ('I exercise because I believe that this will help my daily life functioning'), integrated regulation ('I exercise because it expresses the person I am') and intrinsic motivation ('I exercise because it is fun')]. The Self-Determination Theory hypothesizes that the more an individual's behavioral regulation is self-determined (i.e. highly autonomous and low-controlled motivation), the more the behavior is likely to be sustained in the long run [7].

In addition to the level of self-determined motivation, the level of self-efficacy has also been found to predict long-term exercise adherence [8]. Self-efficacy is defined as the belief of one's capability to perform a task when confronted with specific barriers [9]. It is assumed that individuals with a high level of self-efficacy, i.e. those who believe that they can perform well, are more likely to deal with challenging tasks.

Multiple studies indicated that self-determined motivation is associated with increased physical activity levels [10–12]. Moreover, self-efficacy appears to be essential not only in the adoption (e.g. Sniehotta et al. [13]), but also in the maintenance of physical activity [14]. With regard to resistance exercise, one might expect that older adults have a lower level of self-determined motivation or feel less confident to train at high external resistances compared with low external resistances, resulting in lower adherence rates. However, the literature on strength training currently lacks information on this topic. In aerobic types of exercise, the relationship between exercise intensity and adherence has been discussed. A recent review pointed out that lower intensities are related to higher adherence rates, most likely because of increased feelings of pleasure [15]. The question is whether a similar conclusion can be drawn when considering the external resistance in strength training.

At the end of a structured intervention, there are several motivators and barriers that might influence long-term exercise adherence. Factors related to the training program during the intervention (such as feelings of pleasure) are one important aspect. In addition, one should also consider motives and perceived barriers in older adults related to participation in resistance exercise in general.

Previous literature reviews on physical activity motives and barriers in older adults suggested that they can be categorized into intrapersonal factors, interpersonal factors, and community or environmental factors [16, 17]. Motives and barriers that have been widely reported are physical health conditions, enjoyment, lack of time, motivation or interest, (lack of) social support, care of significant others, subscription costs, and weather conditions (for a review, see Baert et al. [17]). In order to create strategies to avoid that most participants quit exercising as soon as the structured intervention ends, it is important to investigate perceived barriers for adherence to resistance exercise in older adults.

The current study was designed as an exploratory 24-week follow-up of a randomized 12-week resistance training intervention in older adults. The postintervention muscular and functional adaptations of traditional high-resistance training at low repetitions (HIGH) and low-resistance training at high repetitions are reported elsewhere [5]. Two low-resistance exercise protocols were designed: (1) a low-resistance protocol (LOW) in which external resistance was kept constant within one session and (2) a mixed low-resistance protocol (LOW+) in which resistance was increased after 60 repetitions. The rationale behind LOW+ was to investigate the benefits of an additional mechanical stimulus for optimizing muscular gains in protocols with low external resistance and many repetitions. As previously reported [5], the three interventions resulted in similar gains in muscle volume and in muscle strength, except for gains in 1RM, which were greater in both HIGH and LOW+ than in LOW. Self-determined motivation and self-efficacy were measured during and after the supervised intervention and at follow-up, while long-term adherence and perceived barriers for adherence were probed retrospectively at follow-up.

The objective of the present study was to investigate and compare the long-term resistance exercise adherence after HIGH, LOW and LOW+ in order to fill the current gap in the literature. Attention was paid to self-determined motivation, self-efficacy, feelings of pleasure during exercise, and the perceived barriers for adherence after cessation of the supervised intervention. In addition, we explored whether long-term adherence rates could be predicted by self-determined motivation, self-efficacy and behavior during the training intervention.

Methods

Study Design

The current study was designed as an exploratory 24-week follow-up of a randomized 12-week resistance training intervention in older adults [5]. In the initial intervention study, participants were randomly assigned to one of three training interventions: traditional high-resistance training (HIGH, n = 18), low-resistance training (LOW, n = 19), or mixed low-resistance training (LOW+, n = 19). Randomization was stratified for gender, age and baseline isometric knee extensor strength. After stratification into a single category based on gender, age and strength, a subject was asked to blindly pick one out of three cards (representing the training groups). For the next subject in the same category, only two cards were left. This process was continued for each subject. Allocation sequence was concealed to both the subject as well as the investigator.

Exercise sessions were performed at a local fitness center in small groups of maximum 3 participants. Participants who signed up together for the study chose to train together at each session (such as husband and wife, siblings). Other training groups depended on participants' preferred time schedule and often differed between training sessions/days. Social interaction with other participants or regular fitness clients was possible during warming-up and in between exercises, but was much more difficult during the individual resistance exercises because of the placement of the equipment.

Baseline and postintervention measurements were performed from January to March 2012 and from April to June 2012, respectively. After the intervention, all participants were free to decide whether or not to continue the resistance training at their own expense. If an individual decided to subscribe to a fitness center, qualified fitness instructors, who were completely independent of the researchers, designed an individualized training program, irrespective of the training intervention in the study. Therefore, during follow-up, no strict detraining period was applied and fitness instructors were free to prescribe any form of exercise program. The investigators did not interfere in any way in training participation and training program designs so that the follow-up period would more closely resemble real-life situations. In September 2012, all participants were invited to participate in follow-up measurements. These measurements were performed from October to December 2012 (24 weeks after the end of the intervention). The study was approved by the University's Human Ethics Committee in accordance with the Declaration of Helsinki. All participants provided written informed consent.

Participants

Fifty-six community-dwelling older adults between 60 and 80 years old (mean age: 68.0 ± 5.0 years) were enrolled in the initial 12-week intervention study. The detailed exclusion criteria have been published previously [5]. Briefly, volunteers with contraindications for maximal strength testing, with neuromuscular disorders, or with recent training experience were excluded.

Resistance Training Intervention

Training was performed on a leg press and leg extension device (Technogym, Gambettola, Italy). The seated row (Technogym) was added to the training program to provide a more complete workout for participants. Participants exercised three times weekly on nonconsecutive days over a period of 12 weeks (total of 36 sessions). Adherence rates were calculated as the number of training sessions attended as a percentage of the total number of training sessions. In the first session, the proper lifting technique and speed of movement (2 s for each concentric and 3 s for each eccentric action) were demonstrated and practiced. All sessions were supervised by a qualified fitness instructor. After a 10-min warming-up on a cycle ergometer (Technogym Bike Excite, Gambettola, Italy) or on a treadmill (walking pace; Technogym Run Excite), the exercises were performed with at least 2 min of rest in between. The HIGH group performed two sets of 10–15 repetitions. Resistance was initially set at about 80% of 1RM. One minute of rest was provided between sets. The LOW group performed one set of 80–100 repetitions. Resistance was initially set at about 20% of 1RM. The LOW+ group performed a fatiguing protocol of 60 repetitions at an initial resistance of 20% of 1RM, immediately followed (no rest) by 10–20 at an initial resistance of 40% of 1RM. Immediately after each individual exercise, participants graded their level of perceived exertion on the OMNI-Resistance Exercise Scale of perceived exertion (scale from 0 to 10) [18]. In all groups, participants were encouraged to continue the exercise when maximal effort was not achieved after the prescribed number of repetitions. External resistance was adjusted when participants performed repetitions beyond the prescribed training zone, as well as when the rate of perceived exertion dropped below 6.

The number of repetitions performed at every training session for the three exercises were recorded. Performing repetitions beyond the prescribed training zone can be influenced by motivation and can thus differ between training groups. Therefore, we calculated the mean number of repetitions performed by a participant (overall mean of leg press, leg extension and seated row) relative to the maximum number of repetitions in the prescribed zone.

Psychological Processes

Multidimensional Self-Efficacy Questionnaire

Self-efficacy, i.e. the belief of one's capability to perform a task when confronted with specific barriers, was measured by means of an adapted version of the Multidimensional Self-Efficacy Questionnaire that focused on physical activity in general [19]. This questionnaire was adapted so that participants had to indicate their confidence level for performing resistance exercise instead of for being physically active in general. A 5-point Likert scale, ranging from 'not at all confident' to 'very confident', was used. All 12 items began with 'How confident are you that you can perform resistance exercise…' followed by individual items representing common barriers for exercise behavior (e.g. '…when you are too tired'). As this questionnaire is only relevant when individuals are actually engaged in resistance exercise, it was only implemented after 2 weeks of training (before intervention) and following intervention. The internal consistency of the questionnaire was excellent. At pre- and posttest, Cronbach's α coefficients were 0.93 and 0.94, respectively.

Behavioral Regulation in Exercise Questionnaire-2

The degree of motivation was assessed using an adapted (Dutch) version of the Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2) [20]. In this 19-item questionnaire, participants' motivation to participate in resistance exercise, instead of in physical activity in general, was measured. Each item was measured on a 5-point Likert scale (ranging from 1 = 'strongly disagree' to 5 = 'strongly agree'). The relative autonomy index (RAI), i.e. a single score derived from the questionnaire's subscales [amotivation (e.g. 'I don't see the point of doing resistance exercise'), external regulation (e.g. 'I do resistance exercise because other people say I should'), introjected regulation (e.g. 'I feel guilty when I don't do resistance exercise'), identified regulation (e.g. ' I do resistance exercise because I value the benefits'), intrinsic regulation (e.g. 'I do resistance exercise because it's fun')] that gives an index of the degree to which respondents feel self-determined, was calculated. The minimum score for the RAI is –25 and the maximum score is +19. The BREQ-2 was completed after 2 weeks of training (before intervention), following intervention and at follow-up. Cronbach's α coefficients for pre-, post- and follow-up tests were 0.82, 0.85 and 0.76, respectively.

Feelings Related to Exercise

During the 12-week intervention, the following 5 questions were answered by the participants on an 11-point item scale (ranging from 0 = 'not at all…' to 10 = 'very …'), immediately after the second training session each week (12 times in total): (1) How much did you enjoy the strengthening exercises while executing them? (2) How proud are you that you were able to complete these strengthening exercises? (3) How relieved are you that these strengthening exercises are finished? (4) How confident are you that you will be able to complete these strengthening exercises in the next training session? (5) How motivated are you to complete these strengthening exercises in the next training session?

The internal consistency of these feelings was checked with Cronbach's α analysis. As item 3 represents more negative feelings towards exercise, this item was inversely coded in the Cronbach's α analysis. Cronbach's α was 0.63 for the 5 items. However, when item 3 (relief) was deleted, Cronbach's α increased to an acceptable value of 0.76. It was therefore decided to calculate the mean of the four remaining items 1, 2, 4 and 5 into one global scale representing positive feelings related to the training exercise, while item 3 was analyzed representing the item 'relief'.

Long-Term Resistance Exercise Adherence

At follow-up, participants were asked whether or not they continued resistance exercise at a fitness center after completion of the intervention. If the answer was yes, time and date for every training visit in the fitness center and the details of the latest exercise session were retrieved. If the answer was no, participants had to indicate their reasons for quitting by rating their agreement with 16 possible barriers for resistance exercise on a 5-point Likert scale (ranging from 1 = 'strongly disagree' to 5 = 'strongly agree'; see table 3 in the Results section for an overview of the barriers). Participants could add another barrier if a barrier that they considered to be relevant was not included. The listed barriers were inspired by previous research and comparable to other studies [16, 17, 21–24]. Barriers were categorized based on the Social-Ecological Model as a theoretical framework [25]. In this model, behavior is viewed as being determined by the following: intrapersonal factors (e.g. health conditions, motivation, interest, and knowledge), interpersonal factors (e.g. social support and care for others), and community or environmental factors (e.g. cost, access to facilities, and weather conditions). Of the 16 barriers that were listed in this study, 7 were categorized as intrapersonal, 4 as interpersonal and 5 as environmental (see table 2 in the Results section).

Long-term adherence rates were calculated as the number of training sessions performed between postintervention and follow-up as a percentage of the recommended number of training sessions. The recommended number of training sessions was based on international guidelines by the World Health Organization [26]. These recommendations suggest a strength training frequency of two times weekly for older adults. Participants who adhere to at least 80% of the recommended training sessions are defined as adherers. Participants who adhere to less than 20% of the recommended training sessions are defined as nonadherers. Participants who carry out 20–80% of the recommended training sessions are defined as partial adherers.

In addition to the question on long-term resistance exercise adherence, participants were asked whether they had the intention to participate in resistance exercise in the future (yes or no).

Statistical Analyses

Data were initially analyzed for normality with a Shapiro-Wilk test. Nonparametric statistics were used for the psychological process variables, as they were measured on ordinal scales.

χ^2 tests or Fisher's exact tests (when >20% of cells have expected counts of less than 5) were used to determine if the number of yes/no responses to the questions about participation in resistance exercise differed between groups. The same tests were used to check for differences between groups in frequencies of reporting a specific barrier for resistance exercise in general.

One-way analysis of variance (parametric analysis) and Kruskal-Wallis tests (nonparametric analysis) were used to assess between-group differences at baseline and to check for between-group differences in the mean number of repetitions performed (in % relative to the prescribed training zone) and training adherence during the initial 12-week intervention, the feelings related to exercise scales, self-efficacy and RAI at all points in time. When significance was revealed with the Kruskal-Wallis test, Mann-Whitney U tests were used as a post hoc test. Time effects on psychological process variables were assessed with Friedman tests.

Multiple linear regression analysis was used to determine the contribution of several variables to long-term adherence rates. All statistical tests were executed with SPSS software version 19 (SPSS Inc., Chicago, Ill., USA). The level of significance was set at $p < 0.05$.

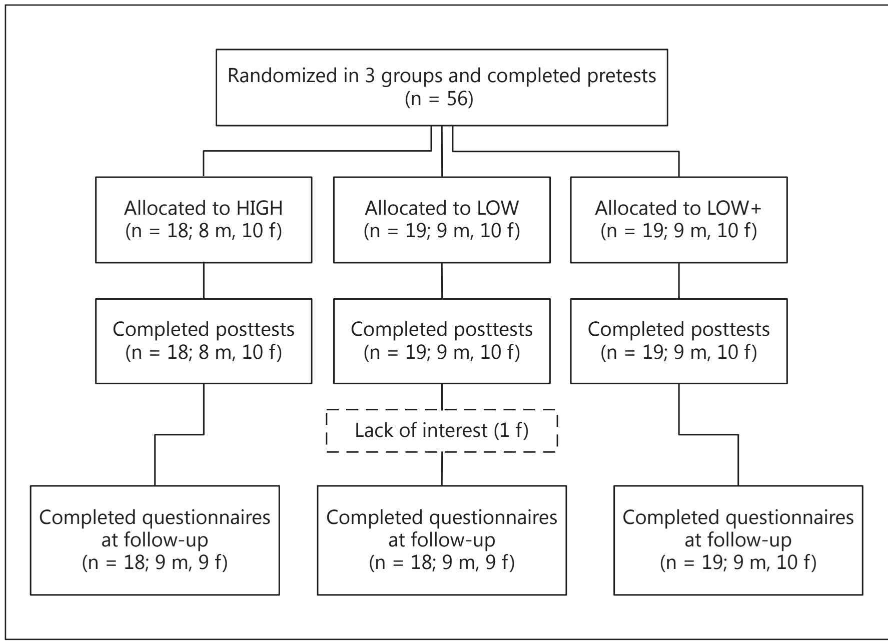

Fig. 1. Flowchart of the study.

Table 1. Means ± SD for subjects' characteristics at baseline

	HIGH (n = 18)	LOW+ (n = 19)	LOW (n = 19)	p
Male/female	8/10	9/10	9/10	
Age, years	67.72±4.28	67.43±5.90	68.76±4.96	0.701
Weight, kg	71.58±11.33	76.63±12.10	75.58±14.77	0.460
Height, m	1.67±0.08	1.66±0.08	1.65±0.09	0.769
BMI	25.54±2.82	27.57±3.08	27.62±4.12	0.117

p values: results of one-way analysis of variance between baseline group means.

Results

Baseline Characteristics and Flow Diagram

Figure 1 shows a detailed flow diagram of the study. Neither the participants' characteristics (table 1) nor any of the outcome variables differed significantly between groups at baseline (all p values >0.05) [5].

None of the participants in the HIGH, LOW or LOW+ group dropped out during the 12-week intervention study. One subject in the LOW group refused to participate at follow-up (fig. 1). No adverse effects of the intervention were reported in any of the groups [5].

Training Adherence and Barriers

Training adherence during the initial 12-week intervention was 95.7% in the HIGH (range: 88.9–100%), 95.8% in the LOW (range: 86.1–100%) and 95.3% in the LOW+ group (range: 80.6–100%), with no significant differences between groups [5]. Only a minority of participants continued (or restarted) strengthening exercises after cessation of the intervention: 3 out of 18 participants in the HIGH (17%), 4 out of 19 participants in the LOW+ (21%), and 2 out of 18 participants in the LOW (11%) group. Fisher's exact tests did not reveal significant differences in frequencies between groups ($p > 0.05$). Of these 9 participants who continued strength training, 6 were partial adherers, with adherence rates ranging from 35.2 to 74.3%. Three participants were considered nonadherers, as adherence rates ranged from 13.7 to 18.9%. Importantly, adherence rates did not differ significantly between HIGH, LOW and LOW+ ($p = 0.349$).

Table 2. Perceived barriers for continuation of strength training after cessation of the supervised intervention

Perceived barriers	Mean ± SD	Subjects grading 4 or 5, %
Intrapersonal factors		
Lack of interest in resistance exercise	2.5±1.1	15.6
Health-related issues	1.8±1.4	15.6
More interested in other physical activities	3.0±1.4	40.0
Resistance exercise is too strenuous	1.9±0.9	4.4
Low outcome expectations	1.5±0.7	0.0
Perceived lack of time	3.1±1.5	45.7
Planned vacation/travel	2.1±1.4	20.0
Interpersonal factors		
Lack of social support	1.4±0.7	2.3
Exercise companion quitted	1.6±1.0	6.7
Care of siblings/others	2.2±1.3	17.4
No continuation of instructor's supervision	2.3±1.3	20.0
Environmental factors		
Financial cost	2.5±1.2	28.3
Seasonal reasons	2.7±1.5	40.0
Lack of access to a fitness center	1.7±1.2	8.9
Fitness centers are too busy	1.7±1.1	6.7
Uncomfortable feeling in fitness center	1.5±1.0	6.7

Barriers were rated on a 5-point Likert scale (ranging from 1 = 'strongly disagree' to 5 = 'strongly agree').

Five participants restarted strengthening exercises within 4 weeks after the postmeasurements. One of them had already quit exercising before follow-up measurements. Four restarted at the beginning of autumn, on average 17.6 weeks after the postmeasurement. Participants who continued strength training completed on average 18.6 exercise sessions (range 7–35) over a period of on average 13.5 weeks (range 6–21). These participants had received an individualized training program, prescribed by qualified fitness instructors and irrespective of the training program during the intervention. In their most recent training program of the follow-up period, 5 participants still trained on the leg press, on which they performed on average 2 sets of 17 repetitions at a resistance of 38% of 1RM measured at follow-up. Also, 5 participants continued exercising on the leg extension, on which they performed on average 2 sets of 16 repetitions at 41% of 1RM measured at follow-up. Although most participants quit strengthening exercises after the intervention, many of them indicated that they were still planning to participate in strength training at a fitness center in the future: 6 out of 17 participants in the HIGH (35%), 12 out of 19 in the LOW+ (63%), and 11 out of 18 in the LOW (61%) group. The χ^2 test did not reveal a significant difference in frequencies between groups ($p = 0.183$).

Table 2 represents the mean values reported on a 5-point Likert scale for the reasons to quit strengthening exercises. We focused on those barriers that were graded 4 (somewhat agree) or 5 (strongly agree). Only two differences were found between groups in the frequency of reporting a specific barrier. More specifically, the barrier of financial cost was less reported by those in the LOW as compared to the HIGH and LOW+ groups ($p = 0.048$), while seasonal reasons were more reported by those in the LOW+ as compared to the LOW and HIGH groups ($p = 0.021$). On average, 50, 31 and 19% of the barriers graded 4 or 5 by an individual were classified as intrapersonal, environmental and interpersonal factors, respectively. The most frequently reported barriers were perceived lack of time (46%, intrapersonal), seasonal reasons (40%, environmental), being more interested in other physical activities (40%, intrapersonal) and financial cost of subscription to the fitness center (28%, environmental) (table 2).

Psychological Processes

A one-way analysis of variance showed no difference in the mean number of repetitions (in % relative to the maximum number of repetitions prescribed) during the initial 12-week training sessions between the HIGH (94.23 ± 7.08%), LOW (91.40 ± 11.67%) and LOW+ (95.90 ± 32.92) groups ($p = 0.797$). The scale measuring participants' positive feelings related to exercise revealed no significant differences between groups at any of the 12 time points nor time effects within groups (fig. 2) (all p values >0.05). In addition, no time effect was found on the scale referring to the questionnaire item 'relief' in any of the groups (all p values >0.05). Only in week 12 did participants in the LOW group indicate that they were more relieved that the exercise session was finished than participants in the HIGH and LOW+ (fig. 3) groups ($p < 0.05$). No differences emerged between groups for self-efficacy and RAI at any of the time points (all p values >0.05). In addition, self-efficacy and RAI did not change over time in any of the groups (all p values >0.05; table 3).

Predictors of Long-Term Adherence

Multiple linear regression analysis was performed with a long-term adherence rate as dependent variable and the following parameters as predictor variable: self-efficacy at posttest, RAI at posttest, positive feelings and

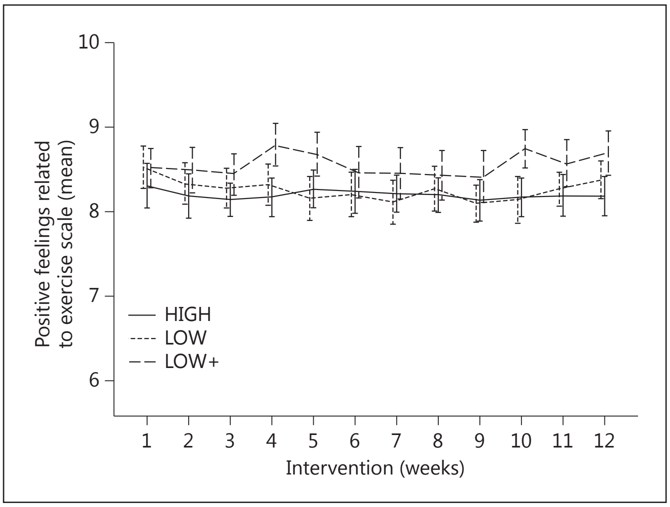

Fig. 2. Graphical representation of the mean scores on the positive feelings related to exercise scale, which was filled out once weekly during the 12-week intervention.

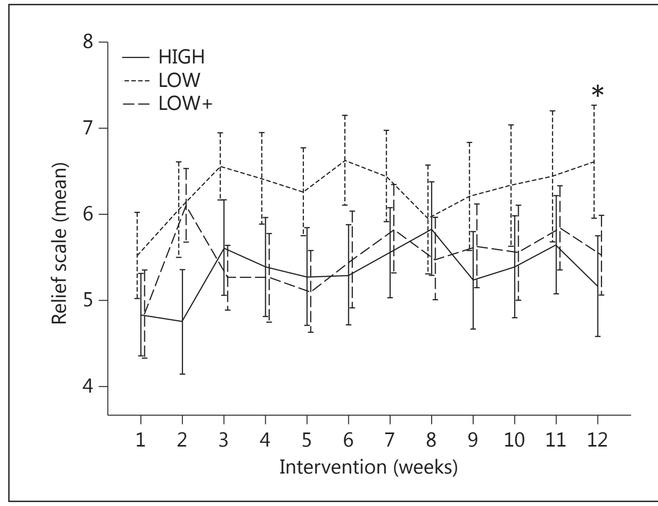

Fig. 3. Graphical representation of the mean scores on the questionnaire item 'relief', which was completed once weekly during the 12-week intervention. * $p < 0.05$, significant difference between the LOW and both HIGH and LOW+ groups at week 12.

feelings of relief related to exercise (at week 12 and mean over 12 weeks), the mean number of repetitions performed (in % relative to the maximum number of repetitions prescribed) and training adherence during the initial 12-week intervention. None of these predictor variables contributed significantly to the long-term adherence rate.

Discussion

The objective of the present study was to compare the level of motivation and long-term adherence after high- and low-resistance exercise interventions in older adults. The results revealed that the degree of external resistance used during the intervention did not influence self-determined motivation during the training, which was high in all exercise groups, nor long-term adherence, which was limited. The most commonly reported barriers for continuing resistance exercise were perceived lack of time, being more interested in other physical activities, seasonal reasons and financial cost. In addition, we explored whether long-term adherence could be predicted by the degree of motivation, self-efficacy or the behavior during the intervention. No significant relationships were found.

In the current study, the older adults appeared to have high levels of self-determined motivation before, during and after the training intervention, with no difference between groups. In addition, they were moderately to highly confident that they would perform resistance exercise when confronted with barriers. One might expect that older adults would have lower levels of self-determined motivation or would be less willing or less confident to

Table 3. Means ± SD for questionnaire variables in the three intervention groups

Variables	HIGH	LOW+	LOW	p
Positive feelings related to exercise (min score = 0, max score = 10)				
Week 1	8.3±1.1	8.5±1.0	8.5±1.1	0.788
Week 12	8.2±1.1	8.7±1.1	8.4±0.9	0.317
Relief (min score = 0, max score = 10)				
Week 1	4.8±2.0	4.8±2.2	5.5±2.2	0.548
Week 12	5.2±2.5*	5.5±2.0*	6.6±2.8	0.042
Self-efficacy (min score = 1, max score = 5)				
After 2 weeks of training	3.7±0.6	3.3±0.7	3.8±0.7	0.105
After intervention	3.6±0.6	3.5±0.5	3.6±0.6	0.806
Relative autonomy index (min score = –25, max score = 19)				
After 2 weeks of training	10.2±4.8	11.0±4.1	9.8±5.1	0.787
After intervention	8.9±5.3	8.6±4.4	9.0±3.5	0.907
At follow-up	8.3±4.3	9.4±4.5	10.0±4.2	0.434

p values: results of the Kruskal-Wallis test. * $p < 0.05$, significant difference with LOW (Mann-Whitney U test). No significant time effects were found.

engage in high- compared to low-resistance exercise, but the findings in the current study do not support this expectation. Older adults participating in the LOW group seemed most relieved that the exercise session was finished, especially in week 12. Interestingly, fewer participants in the HIGH than in the LOW and LOW+ groups intended to participate in strength training at a fitness center in the future, but this difference was not significant. Considering that the actual behavior did not differ between high- and low-resistance exercise, it cannot be claimed that low-resistance exercise is preferred over high-resistance exercise for long-term adherence. This is an important finding, given that low-resistance exercise is often claimed to be more suitable for older adults. However, it should be noted that participants in this study might not be representative of the older population in terms of motivation. A self-selection bias may have occurred, which is inevitable in research that depends on volunteers. Only motivated people engage in exercise interventions, and a ceiling effect in motivation might have masked group differences.

In contrast to the expectations that a high degree of self-determination and self-efficacy for participation in resistance exercise would result in the long-term adherence to exercise [7], only few participants continued strength exercising after cessation of the intervention, and long-term adherence rates were low. This finding corresponds with the experience in previous intervention studies, in which most participants quit exercising as soon as the structured and guided intervention ends, even though they appeared to enjoy exercise participation [22, 27]. The discrepancy between the high degree of motivation and the low long-term adherence rates might be explained by an overestimation of participants regarding their own coping capabilities. Another explanation is that participants might have overreported the motivation and self-efficacy for participation in resistance exercise, considering that people tend to give socially desirable answers to questionnaires [28].

Besides self-reported motivation and self-efficacy, we checked whether behavioral aspects during the intervention were able to predict long-term adherence rates. These behavioral aspects were performing more repetitions than strictly prescribed and training adherence during the intervention. Again, no relationship was found. A reason might be that training adherence could not really discriminate between participants, because it was very high (>80%) in all participants during the intervention. Moreover, the tendency to continue the exercise beyond the prescribed number of repetitions is not only a matter of motivation, but can also be a result of the difficulty to set the optimal training resistance in advance. This difficulty is especially relevant for high-repetition low-resistance exercise protocols, where interindividual differences in strength endurance capacity and daily variability are common.

As reported earlier, only a minority of older adults continued strength exercising after cessation of the intervention (9 out of 56 participants). Even more striking is that long-term adherence rates were low, even in those who continued (or restarted) resistance exercise. None of the participants were considered long-term adherers if we use the WHO recommendations as a reference [26]. Although a year-round resistance exercise training frequency of at least twice per week might be ideal, it might also be interesting to alternate a period of more intense resistance exercise, such as the 12-week intervention, with a less intense period aiming at maintaining training adaptations. The minimum required dose or frequency of exercise for maintaining training adaptations still needs to be investigated more into detail. However, Trappe et al. [29] have already stated that resistance training 1 day a week can be sufficient to maintain muscle strength and volume in older men after a 12-week progressive resistance training program.

Not only adherence rates dropped after the intervention, but training intensities as well. Participants who still trained on the leg press or leg extension in their latest training program performed on average 2 sets of 17 repetitions at 38% of 1RM and 2 sets of 16 repetitions at 41% of 1RM, respectively. These training intensities are markedly lower than the intensities in the initial training intervention [5]. On the one hand, the lower intensities might be caused by the prudence of fitness instructors not to overburden the musculoskeletal system of older adults. On the other hand, older adults might have self-selected their resistances for performing a fixed number of repetitions. The resistances were indeed very similar to the self-selected resistance (42% of 1RM) for performing 10–15 repetitions by apparently healthy older women in previous investigations [30, 31]. Although a self-selection strategy can enhance autonomous motivation [30], inappropriate intensity selection may also undermine training results, hereby discouraging individuals to continue exercising in the long run [31]. Hence, it is crucial for fitness instructors to closely supervise training intensity and individual's perceived effort.

The low long-term adherence rates stress the importance to focus on the barriers for maintaining resistance exercise behavior, a research area that has not yet received sufficient attention in the literature. Classifying the barriers based on the Social-Ecological Model provided us with valuable information on the importance of intrapersonal, interpersonal or environmental aspects. This classification is therefore important to gain a better insight into how to counteract these barriers. In the current study, participants most commonly reported intrapersonal factors as barriers for the maintenance of resistance exercise behavior after the end of the supervised intervention. This is in line with a recent review that concludes that intrapersonal factors are most often reported by older adults as barriers for exercise [17]. It underlines the importance of developing strategies such as motivational coaching and increasing awareness by professionals to counteract these barriers for resistance exercise.

Of the intrapersonal barriers, perceived lack of time (46% of participants) and being more interested in other physical activities (40% of participants) were indicated most frequently. These primary constraints to continue resistance exercise seem to represent motivational problems, which again seems to contradict the high degrees of self-reported autonomous motivation and self-efficacy following intervention. The reported barrier of perceived lack of time also suggests that participants were not able to incorporate resistance exercise in their schedule without professional assistance. In this regard, the abrupt ending of the provided structure and guidance during the intervention seems to be an important issue. Future research should focus on strategies to facilitate the gradual incorporation of resistance exercise behavior in the real-life situation.

Many participants reported being more interested in physical activities other than resistance exercise. This finding highlights the need for increasing the knowledge and understanding of the detrimental effects of sarcopenia on functional performance and of the benefits of resistance exercise in older adults. Nowadays, the majority of older adults believes that the maintenance of a physically active lifestyle, without systematic training, is sufficient to prevent functional dependence as a consequence of aging. However, research contradicts this common belief [32] and points to the necessity of participation in resistance exercise [33–35]. Increasing the awareness of sarcopenia might influence an older adult's motives to engage in resistance exercise. A physician's advice to exercise might play an important role, as it has already been identified as a motivator for older adults [17].

Next to intrapersonal barriers, two environmental factors need to be considered. First, the supervised intervention ended in springtime, near the start of summer (April to June). The changes in weather, i.e. more hours of sun, might have stimulated the engagement in outside activities instead of in resistance exercise sessions at a fitness center. Consequently, 40.0% of participants reported seasonal reasons as one of the barriers for continuing resistance exercise. Second, the financial cost of subscription to the fitness center was pointed out as an important barrier by 28.3% of participants. This is in agreement with a study of Kruger et al. [36], which indicated that US adults commonly perceive subscription fees as a barrier to access fitness facilities.

The main limitation of this study is the limited sample size, which makes it susceptible to type II error. Another limitation is that we obtained only limited information on exercise participation at follow-up. Aside from an overview of the subjects' latest exercise program, no detailed information on program variables was retrieved. Because of this lack of in-depth information on exercise participation during follow-up, we could only compare adherence rates between HIGH, LOW and LOW+.

In conclusion, this study was a first attempt to examine whether older adults would be more motivated to engage in low- as compared to high-resistance exercise, which could lead to differences in long-term exercise adherence. To date, the literature lacked information on this topic, even though it is especially relevant when determining the long-term effectiveness of different resistance exercise protocols in older adults. No differences in self-determined motivation or in long-term adherence were found after the end of a supervised resistance exercise intervention at high or (mixed) low external resistances. The level of self-determined motivation was surprisingly high in all exercise groups, which can be considered an important finding of this study. Contrary to this finding, long-term adherence was low, suggesting the importance of conducting further research on developing strategies to overcome barriers of older adults to engage in resistance exercise.

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Disclosure Statement

The authors declare that they have no conflicts of interest.

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