Cycling as a novel approach to resistance training increases muscle strength, power, and selected functional abilities in healthy older women

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Macaluso, Andrea, Archie Young, Katie S. Gibb, David A. Rowe, and Giuseppe De Vito. Cycling as a novel approach to resistance training increases muscle strength, power, and selected functional abilities in healthy older women. J Appl Physiol 95: 2544–2553, 2003.—Cycling on a mechanically braked cycle ergometer was used as a novel approach to compare the effects of three different 16-wk resistance-training programs on isometric force, power output, and selected functional abilities in 31 healthy 65- to 74-yr-old women. Training was conducted three times per week. During each session, individuals of the speed group performed 8 sets of 16 pedal revolutions at 40% of the maximal resistance to complete two revolutions (2 RM); strength group performed 8 sets of 8 revolutions at 80% of 2 RM; and combination group performed 4 sets of 16 revolutions at 40% and 4 sets of 8 revolutions at 80% of 2 RM. During each session, all participants were required to pedal as fast as possible with a 2-min interval between sets. All training groups significantly increased force, power, and functional abilities (maximal treadmill walking speed, vertical jumping, and box stepping) at week 8 (in the range from 6.5 to 20.8%) with no further improvement at week 16 (except maximal treadmill walking speed), but no significant differences were observed between the three groups. The novel approach to performing both low- and high-resistance training, based on the use of a cycle ergometer, has been shown to be effective in improving strength, power, and functional abilities in a group of healthy women. Even fit older women can still improve in functional abilities. Interestingly, the “high-speed” and “low-speed” programs induced an increase in both power and strength of similar magnitude.

Because women may reach levels below the thresholds for tasks important for an independent life, it is reasonable to consider them as the first target of any intervention program. Moreover, power output has been shown to be more predictive of functional difficulties than strength per se. In recent times, greater attention has been focused on the need to design exercise strategies to increase muscle power in older populations. Traditional low-velocity resistance-training programs resulted in much larger increases in muscle strength than power (10, 27, 44), and therefore protocols that induce power-specific adaptations have to be identified (8, 9, 11).

In the present study, cycling was used as a novel approach to compare the effects of three different 16-wk resistance-training programs on isometric force, power output, and selected functional abilities in a group of healthy women aged 65–74 yr. Our hypothesis was that the high-speed program would have induced

CRITICAL LEVELS OF MUSCLE POWER, which is the product of both force and velocity of movement, are necessary in older people to accomplish daily living tasks like climbing stairs, rising from a chair, or using public transport. Aging leads to a considerable decrease in strength and even greater disadvantage in power output. Because women may reach levels below the thresholds for tasks important for an independent life, it is reasonable to consider them as the first target of any intervention program. Moreover, power output has been shown to be more predictive of functional difficulties than strength per se. In recent times, greater attention has been focused on the need to design exercise strategies to increase muscle power in older populations. Traditional low-velocity resistance-training programs resulted in much larger increases in muscle strength than power (10, 27, 44), and therefore protocols that induce power-specific adaptations have to be identified (8, 9, 11).

In the present study, cycling was used as a novel approach to compare the effects of three different 16-wk resistance-training programs on isometric force, power output, and selected functional abilities in a group of healthy women aged 65–74 yr. Our hypothesis was that the high-speed program would have induced
power-specific adaptations, whereas the low-speed program would have induced strength-specific adaptations.

METHODS

Participants

With ethics committee approval, 38 participants [age 69 ± 2.7 yr (mean ± SD); stature 1.58 ± 0.05 m; body mass 63.5 ± 11.3 kg] were selected according to the exclusion criteria to define “medically stable” older participants for exercise studies, as proposed by Greig et al. (15). Volunteers provided written, informed consent for participation in the study. Participants were allowed to be involved in regular physical activity no more than two times per week and were required to maintain their normal levels of physical activity throughout the duration of the study. This was monitored through weekly activity logs. After completing the familiarization procedures, all participants were tested on two occasions before the onset of the training (week -4 and week 0). The 4-wk interval of time between these two testing sessions was used as a control period, as in other recent training studies (17, 25, 29, 39). The measurements were then repeated halfway through the training (week 8) and at the end of it (week 16). At week 0, participants were assigned to one of three groups, which were matched for age and knee-extension MVC: speed (SP), strength (ST), and combination (CB). Of the 38 volunteers initially enrolled in the training program, 31 completed the training program (10 SP; 10 ST; 11 CB). Six of the older women who were initially enrolled in the training program, but attended only 1 or 2 of the initial training sessions, were asked anyway to attend the testing sessions at weeks 8 and 16, as those who attended the training program. They were therefore designated the “withdrawal” group (WT).

Dynamometric Measures

Both isometric MVC and power output measures were made on the dominant lower limb by using a dynamometer (Kin Com, Chattanooga, TN). The dominant limb was determined by asking the participants which leg they use to kick a ball. Participants warmed up on an exercise bicycle for 5 min at a low resistance before performing any strength and power test. MVC was measured during knee extension (KE), knee flexion (KF), and leg press (LP). During the KE and the KF, participants were seated comfortably in the dynamometer chair, with their trunk erect and fastened by three crossing belts. They were positioned so that a 90° angle at the knee joint was obtained. During the LP, the seat was modified to have a firm support placed behind the buttock (32). The trunk was fastened by three crossing belts, and each participant’s leg was positioned so that a starting angle of 90° at the hip, knee, and ankle joint was obtained. The MVC task consisted of a quick increase to a maximum in the force exerted by the leg. A target line was always set on the computer screen at a value 20% higher than the best performance. Participants were able to follow their performance on the computer screen and were verbally encouraged to achieve a maximum and to maintain it for at least 2 s before relaxing. MVC was calculated as the largest 1-s average reached within any single force recording. A minimum of three attempts was performed separated by 3 min, and the highest of these attempts was chosen as MVC. Participants were asked to make a further attempt if the MVC of their last trial exceeded that of previous trials. Power output was measured during the LP, starting from the position adopted to measure MVC. The dynamometer was set in the “isotonic” mode, with the initial load at 40% MVC. The test was then repeated with the initial load increased, in 10% increments, up to 80% MVC in a random order. Each participant was required to push forward, as strong and quickly as possible, until the leg was fully extended throughout a range of motion of 0.2 m. Three trials for each level of initial load were performed in a random order. Maximal power output was calculated as the product of the force at the instant in which it reached the user-selected level, and the corresponding speed, i.e., peak speed. The highest of these attempts was chosen, regardless of the initial resistance. In addition, at weeks 0, 8, and 16, each participant was also asked to push the same levels of initial resistance as performed at week -4 to compare power output and speed at power output measured starting from the same condition. Repeatability of these measurements has been published in a previous investigation (32). As already reported (32), although the dynamometer has been set in the isotonic mode, force is not kept constant during the movement, which cannot therefore be referred to as isotonic. The dynamometer attempts to hold the lever arm resistance at the user-selected level by reading the load-cell signal and adjusting the speed of the motor potentiometer throughout the full range of motion, but the sampling rate of the instrument (100 Hz) is such that the adjustment is not quick enough to obtain a constant trace. However, it must be clarified that the fact that the dynamometer is not “strictly” isotonic does not affect the substance of our results. To calculate power, it was necessary to adopt a dynamometer that enabled measurement of velocity of movement with the subjects exerting a given level of average force throughout the movement, which always corresponded to the user-selected level.

Functional Ability Tests

Functional ability tests included 1) maximal treadmill walking speed (MTWS), 2) vertical jump (VJ) on a force platform adopting a countermovement-jumping test (6), and 3) box-stepping test. MTWS was tested on a motorized treadmill (Startrac). Participants were encouraged to walk using their normal gait pattern and to swing their arms by their sides without the use of the handrail; however, during the initial familiarization sessions, the use of the handrail was permitted if the participant experienced problems with balance. Two additional sessions of familiarization were carried out for this test to guarantee that all of the participants were able to walk comfortably. The treadmill was set at an elevation of 5%, which corresponds to the maximal elevation permitted for a 10-m-long wheelchair-access ramp (7). It was decided that, because of the participants’ level of fitness, the treadmill should be elevated for the test to be discriminatory and more sensitive to changes in performance. The participants were asked to walk on the treadmill for a 2-min period at a comfortable speed, within a range of 3–5 km/h with a slope of 0%. The slope was then adjusted to 5% and the speed increased every 5 s by 0.5 km/h until the participant began to move backward. The speed of the treadmill immediately before that in which the participant began to move backward was defined as MTWS. The 5-s duration of each step was a compromise between avoiding fatigue and allowing the participant to become accustomed to the increments in speed. Each participant completed three trials, and adequate time was allowed between trials for recovery. The fastest of the three trials was selected for further analysis. A VJ from both feet was performed on a force platform (Kistler 9261). The participants performed a countermovement jump, which started from a standing position, followed...
Surface Electromyogram

A simultaneous reading of the surface electromyogram (sEMG) from vastus lateralis and biceps femoris muscles was recorded during the measure of the KE MVC. The assumption was made that these two muscles were representative of their constituent groups (4). Bipolar electrodes (Medicotest, type N-10-A, Denmark) with a 20-mm interelectrode distance centered on the muscle were placed around the ankle of the contralateral limb. The sEMG signal was band-pass filtered between 5 and 1,000 Hz (NeuroLog Filter NL125, Digitimer), with a 2,4, and 6 kg were progressively added. The height of the box corresponds to the step heights of public transport and the weights added to the jacket are considered to be roughly the equivalent of a day’s basic necessity shopping (42). The performance in this test was quantified and reported as mechanical work performed (box-stepping work (BSW)), obtained as the product of force (body weight and additional weights in the jacket) and distance (height of the step).

Lower Limb Volume

Lower limb muscle plus bone volume was estimated from anthropometric measurements of segmental circumferences and lengths, as described by Jones and Pearson (26), to monitor changes in muscle mass. Skinfold measurements were made at four sites (anterior, posterior, mid-thigh, and lateral, medial mid-calf) by using skin calipers (John Bull). Skinfold corrections were made by using the following regression equations (P. R. M. Pearson, personal communication): anterior thigh ($y = 4.0836 + 0.407 \times$ skinfold value), posterior thigh ($y = -9.4016 + 0.992 \times$ skinfold value), medial calf ($y = 1.2729 + 0.477 \times$ skinfold value), and lateral calf ($y = 2.0945 + 0.339 \times$ skinfold value), where $y$ represents the corrected skinfold value used in the calculations.

Training Program

Training was conducted three times per week for 16 wk on a mechanically braked cycle ergometer (Monark, model 824E). To determine the individual training workload, participants were tested for the maximal resistance to complete two pedal revolutions, which will be referred in this manuscript as 2-RM; maximum (2 RM). A 2-RM was secured around each participant’s waist to ensure that she was unable to rise from the seat. Starting from the load at which participants could not move the pedals, the load was reduced by 0.5-kg decrements until participants were able to complete two pedal revolutions. Then, to ensure that the selected load was effectively the maximum, participants were required to perform further attempts when the load was increased by 0.5-kg increments. The 2-RM test was performed before the training (week 0), and then every 4 wk (weeks 4, 8, 12, 16) to update the training load.

In each training session, SP performed 8 sets of 16 pedal revolutions at 40% of 2 RM; ST performed 8 sets of 8 revolutions at 80% of 2 RM; and CB performed 4 sets of 16 revolutions at 40% and 4 sets of 8 revolutions at 80% of 2 RM. In each set, all participants were required to pedal as fast as possible with a 2-min interval between sets.

Statistical Analyses

All data were normally distributed in terms of skewness and kurtosis (all values < 2). A mixed model factorial ANOVA with one between-subjects factor (group) and one within-subjects factor (time) was used to separate the variance components within the overall design. Within the training period (from week 0 to week 16), Tukey’s honestly significant difference test was used for two types of simple effect test (28): 1) comparisons across time (week 0 vs. week 8 vs. week 16) separately for each group and 2) comparisons between groups (SP vs. ST vs. CB vs. WT) at each time point. Thus, within each of these facets of the overall design, all possible simple comparisons were made, satisfying the rationale for using the Tukey’s honestly significant difference test (see, for example, Refs. 28, 35). Fisher’s least significant difference test with Bonferroni adjustment was used for comparisons within the control period (from week 0 – 4 to week 0). All significance tests were conducted at a familywise alpha level of 0.05, i.e., at a per comparison alpha level of 0.05/3 (equal to 0.016) for comparisons across time and 0.05/4 (equal to 0.0125) for comparisons between groups.

Intervention Safety and Compliance

Of the 38 volunteers initially enrolled in the training program, 31 completed the final testing (82%). Six of the seven dropouts withdrew after the first or second session of...
training, two for health-related issues (back pain and a spur on the heel) and four for personal reasons, which included lack of time due to other commitments such as caring for older friends or relatives. Another volunteer abandoned after 8 wk of training due to family problems. Compliance with the training program was assessed by the number of exercise sessions attended divided by the number of sessions held. Exclusion criteria set before the onset of the study were 1) missed >1.5 wk of consecutive training or 2) performed <75% of the total number of sessions. No participants were excluded on the basis of these preset criteria. Mean participation rate was 93% for SP, 89% for ST, and 91% for CB.

RESULTS

Dynamometric Measures

Figure 1 shows the results of 1) the 2-RM test, 2) the MVC during the LP, and 3) the MVC during the KE. Figure 2 shows the results of 1) maximal power output of the LP, and 2) force and 3) speed at which maximal power was measured; 4) power output of the LP measured pushing 5) the same level of force as at week 0, and 6) speed at which power output was measured in this condition.

Across-time comparisons. During the control period (from week −4 to week 0), most of the outcome variables did not significantly change. The significant increase in a few outcome variables may be attributed to a learning effect that could have been avoided by performing a higher number of familiarization sessions. During the training period, 2 RM, MVC in both the KE and LP, and maximal power output of the LP significantly increased in all three training groups (SP, ST, and CB) from weeks 0 to 8 and from weeks 0 to 16. Only in one of these outcome variables (2 RM) was there a further significant increase from week 8 to week 16. There was a consistent pattern of increase of the two determinants of maximal power output of the LP (force and speed) from week 0 to week 8, but only speed significantly increased, and this was true only for the SP group (Fig. 2, B and C). Power output of the LP (measured pushing the same level of force as at week 0) and the relative speed at power output significantly increased in all three groups from week 0 to week 8 but only in SP from week 0 to week 16 (Fig. 2, D and F). In the WT control group, there were no changes across time from week 0 to week 8 and from week 0 to week 16 for any variable.

Between-training groups comparisons. There were no significant differences between the three training groups in any of the outcome variables at any time point (weeks −4, 0, 8, and 16).

Functional Ability Tests

Figure 3 shows the results of the functional ability tests: MTWS, VJ, and BSW, respectively.

Across-time comparisons. MTWS, VJ, and BSW significantly increased in all three training groups (SP, ST, and CB) from week 0 to week 8 and from week 0 to week 16. Only in one of these outcome variables (MTWS) was there a further significant increase from week 0 to week 16.
week 8 to week 16. In the WT control group, there were no changes across time from week 0 to week 8 and from week 0 to week 16 for any variable.

Between-training groups comparisons. There were no significant differences between the three training groups in any of the outcome variables at any time point (weeks –4, 0, 8, and 16).

sEMG

Figure 4 shows the results of sEMG: 1) RMS and 2) MDF of the vastus lateralis during the MVC KE, and 3) percentage coactivation of the biceps femoris during the MVC KE, expressed as a percentage of maximal biceps femoris RMS measured during the MVC KF.

Across-time comparisons. In SP and CB, RMS significantly increased from week 0 to week 8, but there was no further significant increase from week 8 to week 16.

In ST, RMS did not change from week 0 to week 8, but it significantly increased from week 8 to week 16. No significant changes were observed in the level of coactivation of the biceps femoris during the MVC KE between any of the time points for any of the groups. Similarly, there was no change in MDF between any of the time points for any of the groups.

Between-training groups comparisons. There were no significant differences between the three training groups in any of the sEMG variables at any time point (weeks –4, 0, 8, and 16).

Lower Limb Volume

There were no significant changes in body mass or lower limb volume between any of the time points for any of the groups. Additionally, there were no signifi-
Fig. 3. Means ± SE of maximal treadmill walking speed (MTWS; A), vertical jump (VJ; B), and box-stepping work (BSW; C) in the 4 groups. a Significantly different from week 0 to week 8. b Significantly different from week 0 to week 16. c Significantly different from week 8 to week 16.

Fig. 4. Means ± SE of root mean square (RMS; A) and median frequency of the power spectrum density (MDF; B) of the vastus lateralis during the knee extension MVC. C: percent coactivation of the biceps femoris during the knee extension MVC, expressed as a percentage of maximal biceps femoris RMS measured during the MVC knee flexion, in the 3 groups. a Significantly different from week 0 to week 8. b Significantly different from week 0 to week 16. c Significantly different from week 8 to week 16.
Dynamometric Measures

MVC of both the LP and KE significantly increased in the three groups after 8 wk of training, but there was no further significant increase from week 8 to the end of the training program. This was similar to the observation of Häkkinen et al. (18), who reported a plateau after 8 wk of resistance training in an older population of similar age to that of our participants. In their study, the investigators observed an additional increase in strength only at the end of 21 wk of training, which could be attributed to the fact that the training intensity was further increased after 16 wk. In our study, further improvement might have been achieved if the intensity had been increased at more frequent intervals, e.g., weekly. Interestingly, the time course and the relative magnitude of the increase in MVC were similar for both LP and KE, in agreement with the recent results of Fielding et al. (11).

The 2 RM was the only dynamometric measure showing a progressive increase also between week 8 and week 16. This variable was not measured at week 4, because it was initially designed only to determine and update the training load (see Fig. 1A). These results support the findings of previous authors (e.g., Ref. 13) who reported a greater improvement when the testing procedure was closely linked to the specific training maneuver.

Maximal power output was evaluated by means of a recently devised test (32), which allows selection of the optimal load for maximal power production during a multijoint functional maneuver in vivo involving lower limb muscles used during activities of daily living. This can be considered an improvement with respect to other traditional devices like the force platform (3, 6) or the Nottingham Rig (1, 42), which adopted a fixed inertia, represented by the participant’s body weight or by a flywheel system, respectively. This is a limitation because the weaker participants may be disadvantaged by pushing a resistance corresponding to a high percentage of their maximum, thus performing the movement at a speed below the optimum for maximal power production. Only recently, Fielding et al. (11) used a pneumatic device, which allows the selection of different loads for measuring power output. However, these authors did not comment on optimal force and velocity at which maximal power output was measured. In our study, there was a significant increase in LP maximal power output in the three groups after the 16-wk training program. This result was due to a combined increase of both force and speed at which maximal power was measured, although the increases in these two outcome variables were not statistically significant, with the exception of speed at week 8 in the SP group. This exception could reflect a specific adaptation in those participants who were trained to pedal faster. Another specific adaptation of the participants in the SP group was observed when power output of the LP was measured when pushing the same level of force of the pretraining test (Fig. 2E). All three groups significantly increased speed of execution (Fig. 2F) and relative power (Fig. 2D) at week 8, but this improvement was still significant at week 16 only in the participants of the SP group.

The improvement in muscle function, either strength or power output, was not different between the three groups, thus indicating that the major determinant of training efficacy may be represented by the mechanical work performed irrespective of the speed of execution. This is similar to the results reported by previous authors (23, 40), who have compared the effects on muscle strength of two different training regimens performed with traditional weight-stacked machines, one at high intensity and another at low intensity, with the total mechanical work being the same in the two conditions. However, recent results of Fielding et al. (11) suggest that this may be true for strength but not for power. In their study, the authors showed that individuals of the high-velocity group improved their strength similar to the individuals of the low-velocity group, with the total work performed being the same in the two groups, but showed a higher improvement in power. The specific increase in power has been attributed to the fact that, during training, power output was significantly higher in the high-velocity group. In our study, not only was mechanical work similar in the two conditions but also power output was similar, although this was not systematically monitored. In fact, the time taken to perform either 16 repetitions at 40% of 2 RM or 8 repetitions at 80% of 2 RM was randomly measured in some of the training sessions and was similar in the two conditions. It is therefore likely that the increase in strength depends on the mechanical work performed, regardless of speed of execution, whereas the increase in power is related to power generated during the training sessions. Finally, another possible explanation for the lack of differences in power-specific adaptations between the groups could be that during the training sessions both the slow speed, which was estimated to be ~4 rad/s, and the fast speed, which was nearly doubled, were relatively slow with respect to the maximum angular velocity of the knee in unloaded conditions, which was estimated to be ~12 rad/s (48). To observe power-specific adaptations of higher magnitude, the velocity of movement might have to be closer to the maximal speed of shortening.
Functional Ability Tests

MTWS significantly increased throughout the whole duration of the training program. The ability to increase walking speed and quickly reach a maximum can be useful in some situations of daily life, for example when older individuals are crossing the road. It must be noted that the older women in this study were already walking at relatively fast speeds before training, and it is therefore likely that the improvement would have been even higher if the participants had been less fit (31). Inclusion of dynamic exercises in training may have explained this improvement, as well as that observed in a previous investigation by Häkkinen et al. (16).

The jumping test has been adopted in this study because it is a good indicator of functional ability in an older population (6). Peak power generated during a countermovement jump on a force platform significantly increased in all three groups from week 0 to week 8 and week 0 to week 16. This is in agreement with the results of Häkkinen et al. (16), who reported an increase in the jumping ability of an older population after a 24-wk resistance/dynamic exercise program. Similarly, De Vito et al. (5) observed an improvement in maximal instantaneous peak power measured during a VJ on a force platform in a population of older women after a 12-wk nonspecific low-intensity training program.

The box-stepping ability of older women improved as an effect of training. This is in agreement with the results of Skelton et al. (44), who have shown an increase in box stepping after a 12-wk resistance-training program. Box stepping can be associated with the ability to climb stairs and, therefore, can be considered a crucial factor contributing to the independence of older people. The box heights used in the protocol were designed to imitate the step heights that would be encountered on public transport, both buses and trains (42). In the present study, the weight jacket was included as an integral part of the test to make it more demanding and discriminatory for the fit population of this study. The weights (2, 4, and 6 kg) were chosen because 4 kg is approximately equivalent to a day’s basic-necessity shopping (42), although it could be argued that women do not carry their shopping on a backpack.

sEMG

The sEMG variables, when analyzed in the time domain, have revealed that there was an increase in the level of neural activation of the agonist muscles during the KE (increase in RMS) with no change in the level of coactivation of the antagonist muscles. The first observation is in agreement with previous findings (16, 17, 19, 37), whereas the lack of change in coactivation of the antagonist muscles during the KE is in contrast with the results of previous studies (16, 17). This could be attributed to the fact that previous investigators have trained their participants to perform the KE and have then tested them by using the same specific maneuver, whereas the cycling action of our participants may have not affected the coactivation of the knee flexors during the KE. It is unclear and difficult to interpret why the temporal pattern of RMS increase was different in ST from that in SP and CB. The analysis of the sEMG data in the frequency domain showed that no changes occurred in MDF as an effect of training. This lack of change may indicate that either no adaptations in the type and recruitment of MUs took place or, more likely, the analysis of the frequency contents of sEMG is not such a sensitive measure, despite the evidence of correlation with fiber-type proportion (14, 30, 38, 50).

Suggested Mechanisms of Adaptation

In our laboratory setting, no detailed anatomic measures were possible, nor was it possible to obtain muscle biopsy samples. Lower limb volume was indirectly estimated from anthropometric measures, according to Jones and Pearson (26), which is a limitation, because it is unlikely that the anthropometric measures could detect any small change in muscle mass after the training program. Therefore, it is not possible to exclude the possibility that some concomitant intramuscular adaptation took place. These include an increase in muscle mass (21) and protein synthesis (47, 51), a selective hypertrophy of type II fibers (24), or an adaptation toward faster contracting single fibers (45). Notably, Van Cutsem et al. (46) have shown that changes in single motor unit behavior contribute to the increase in contraction speed after dynamic training in humans, which could partly explain training-induced changes in power. Moreover, our training interventions may have increased tendon stiffness, as recently shown by Reeves et al. (41) in 74-yr-old men after 14 wk of resistance training, which may have increased the effectiveness of force and power transmission.

Intervention Safety and Compliance

The majority of the volunteers showed enthusiasm for the exercise classes and expressed hope that the program could be continued. One of the main advantages of using a cycle ergometer in carrying out resistance-training programs is that in the same training session several individuals can be trained at the same time under the strict supervision of one instructor, which is realistic in terms of feasibility and costs if an appropriate number of mechanically braked cycle ergometers is available. This training program has been proven to be safe and effective and might be feasible also with more frail individuals.

Limitations

The significant increase in a few outcome variables during the control period (from week -4 to week 0) may be attributed to a learning effect that could have been avoided by performing a higher number of familiarization sessions. A limitation of this study is that for these variables that increased during the control period it is difficult to establish where the learning effect is fin-
ished, thus misjudging the true baseline of the measure. However, as these variables continued to increase in the three training groups and not in the withdrawal control group, these changes can certainly be attributed to training. A further limitation of this study is that the WT control group was made by participants who withdrew from the intervention for various reasons, thus opening the question of whether their motivation had an influence on their capacity to maximally perform during the measurement sessions.

In conclusion, the main finding of this study is that the novel approach to performing both low- and high-resistance training, based on the use of a cycle ergometer, has been shown to be effective in improving strength, power, and functional abilities in a group of healthy women. Even fit older women can still improve in functional abilities. For most of the outcome variables, the improvements were evident at the end of 8 wk of training with no further improvements at completion of 16 wk. No differences were observed between the three training groups, and this could indicate that the major determinant of training efficacy is represented by the mechanical work performed, which was similar in all groups, regardless of the speed of execution.

DISCLOSURES

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