Estimation of the Efficacy of Inertial Training in Older Women

Wioletta Brzenczek-Owczarzak, Mariusz Naczk, Jaroslaw Arlet, Justyna Forjasz, Tomasz Jedrzejczak, and Zdzislaw Adach

This study aimed to estimate the efficacy of inertial training in older women using the Inertial Training and Measurement System (ITMS), an original device. Forty-five active women age 53–74 yr performed inertial training with 2 different loads (0 or 5 kg) 3 times weekly for 4 wk. Training sessions consisted of exercises involving the shoulder muscles of the dominant and nondominant arms. The maximal torque and power developed by the dominant and nondominant arms in the 0-kg and 5-kg groups were significantly greater after 4 wk of inertial training (with the exception of torque for the nondominant arm in the 5-kg group; \( p > .05 \)). Thus, short-term training using the ITMS is efficacious and can be used in older women to improve strength and power. However, ITMS training-induced changes in older women are greater after application of smaller external loads.

Keywords: ITMS, muscle strength, power, elderly

Age-dependent changes in the neuromuscular system lead to decreases in muscle strength and power. These changes include the decline of muscle mass, reduction in the cross-section of Type II fibers, a decrease in muscle-fiber contraction velocity, and a decrease in the rate of torque development in leg muscles (Chang, Mercer, Giuliani, & Sloane, 2005; Goldspink, 2012; Merletti, Farina, Gazzoni, & Schiorni, 2002). Older adults also experience impairment of neural control, for example, slowdown of motor nerve-conduction velocity (Bazzucchi et al., 2005; Enoka, 1995) and a drop in activity of anaerobic enzymes (Kaczor et al., 2006). Decreased total activity and sarcopenia also reduce energy expenditure in older adults (Navarro, López-Cepero, & Sánchez del Pino, 2001). Functional changes are the main causes of problems with balance; falls are the most common accidents in older adults, with 30–40% of all people age 65 years and older reported to fall at least once per year (Hill et al., 2004). Functional changes also lead to difficulty in maintaining independence in the activities of daily living of older adults (Hunter, McCarthy, & Bamman, 2004).

Strength training is recommended for older adults to improve quality of life and prevent falls (Persch, Ugrinowitsch, Pereira, & Rodacki, 2009). Resistance exercises cause significant increases in muscle mass, strength, power, daily energy...
expenditure, and bone mineral density in older adults (Ferri et al., 2003; Hunter, Wetzstein, Fields, Brown, & Bamman, 2000; Marques et al., 2011; Navarro, López-Cepero, & Sánchez del Pino, 2001). The American College of Sports Medicine and the American Heart Association suggest that older adults perform resistance exercises involving the major muscle groups at least twice per week (Nelson et al., 2007).

One of the many strength-training methods is the inertial method, which, unfortunately, is rarely used, especially in older adults. Previous investigations have detected significant increases in muscle strength and power after only a few weeks of inertial training in young and middle-aged people (Albert, Hillegass, & Spiegel, 1994; Romero-Rodriguez, Gual, & Tesch, 2011; Seynnes, de Boer, & Narici, 2007; Tesch, Ekberg, Lindquist, & Trieschmann, 2004). Other research has suggested the occurrence of greater eccentric quadriceps activation after inertial exercise than after other forms of resistance exercise (Matheson, Kernozek, Fater, & Davies, 2001; Norrbrand, Pozzo, & Tesch, 2010). In addition, Onambele et al. (2008) observed a greater increase in quadriceps power and gastrocnemius muscle-tendon stiffness after inertial training than after weight training, an increase that was also associated with a larger increase in postural balance. However, McLoda, Murphy, and Davison (2003) did not note any changes in parameters measured in groups of baseball and softball players. These contrasting results may have resulted from methodological differences in the studies.

Two inertial devices were used in most previous investigations: the Impulse training system and the YoYo ergometer. These devices are user friendly, but the range of motion is limited in the case of the Impulse system. Due to the small number of available gravity-independent devices, we decided to construct the Inertial Training and Measurement System (ITMS), which allows exercise throughout the entire range of motion and the application of different movement models using variable loads. Moreover, the construction of the device permits reduction of the influence of gravity on the skeletal system, making this training method safe. Safety is also enhanced by use of the tonic technique during exercise. For these reasons, ITMS training can be used for muscle-strength and -power improvement in older adults.

The aim of this study was to estimate the efficacy of short-term inertial training in older women using the ITMS.

Method

Participants

Forty-five active women age 53–74 years participated in this study (Table 1). The subjects were randomly divided into two training groups and a control (no intervention) group. The first group (Group 0 kg) participated in training with no load in addition to the weight of the device wheel (19.4 kg), while in the second group (Group 5 kg), the device wheel was loaded with an additional 5 kg. Subjects participated in classes organized by the Third Age University (gymnastics, swimming, and Nordic walking) three times per week (× 45 min) and were required to maintain their regular, everyday activities during the training period. None of the women
had contraindications for participation in the training, and all subjects provided informed written consent to participate in the study. All procedures were approved by the local ethical committee, with approval based on the Declaration of Helsinki.

**Device**

Training was performed with the ITMS (Figure 1), which was designed and constructed by an interuniversity group from the Faculty of Physical Culture and the Faculty of Mechanics. The ITMS consists of steel frames fixed to the ground with flywheels (inertial wheels) placed inside. A rope is mounted on the circumference of the wheel. Before exercise, subjects were seated on a bench (Figure 2) and the length of the rope was adjusted to the distance between the device and the bench. Subjects started in the “0” position with arm abducted (from trunk) and with the rope fully extended and tense. To begin exercising subjects pulled the rope by adducting their arm and moving the flywheel (the wheel rotated approximately 90°).

**Training**

Inertial training was performed three times per week (every Monday, Wednesday, and Friday) for a period of 4 weeks. Each training session included three sets of exercise involving the shoulder muscles. One set included abduction and adduction of the right and left arms (without rest) at the shoulder with the subject positioned laterally to the device and (without rest) flexion and extension of the right and left arms (without rest) at the shoulder with the subject positioned in front of the device (abduction and extension were passive, because they were forced by the device). A 2-min break occurred between consecutive sets. In the starting position (during abduction-adduction exercises), the arm was abducted from the trunk approximately 90° (to the shoulder level) or it was raised to shoulder level (during flexion-extension). Subject positioning during ITMS training is shown in Figure 2 (the nearest and farthest women depicted in the photograph). Participants were asked to exercise at maximal speed, irrespective of load. This training regimen had tonic character, a constant tension on the rope during transitions from concentric to eccentric muscle loading. This technique ensures greater joint stability in comparison with the phasic technique (Albert & Thein, 1995). The work time of one

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<th>Table 1 Biometric Characteristics of the Study Participants, $M \pm SD$</th>
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<td><strong>Group</strong></td>
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<td>Age (years)</td>
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<td>Height (cm)</td>
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<td>Body mass (kg)</td>
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*Note.* The 0-kg group trained with no additional load (the load was equal to the mass of inertial wheel). The 5-kg group trained with the exercise trainer wheel loaded with an additional 5 kg.
limb in one plane amounted to 20 s, with a total work time for one arm of 120 s per training session (three sets and two planes). Each training session was preceded by a standard warm-up that lasted approximately 5 min. Warm-up consisted of two sets of 10 double-arm rotations, opposite arm swings, and lateral arm swings with trunk rotation. Two sets of 10 slow cycles with the ITMS were subsequently performed. Each participant used her assigned training weight of 0 or 5 kg.
Measurements

Before and after the training period, both the maximal torque and the power achieved under isokinetic conditions were determined using a specialized dynamometer, the Biodex 4 Pro (USA). Measurement sessions were preceded by a trial session. Biomechanical measurements were taken with the subject in a seated position, with one hand on the device handle and the other on the abdomen, during abduction and adduction of the dominant and nondominant arms at the shoulder joint (Figure 3). To minimize activity of untargeted muscle groups, the participant’s trunk was stabilized by belts across the chest (Figure 3). Before the measurements, the participants were given verbal instructions on the testing protocol. Each experiment began with two trial cycles, each composed of adduction and abduction of the upper extremity, followed by five cycles (involving maximal strength) at an angular speed of 180°/s (π radians/s) and ranging from 10° to 90°, where 0° corresponded to complete adduction of the arm to the trunk.

Each experimental session was preceded by the same warm-up as the prior training sessions (excluding the warm-up using ITMS). Only data recorded during the adduction phase were used in further analyses because inertial exercise involved mostly the shoulder adductors. Measurements taken before and after a 4-week training program were taken at the same time of day for every subject.

Statistical Analysis

Data were analyzed with the R Project for Statistical Computing (R version 2.7.1, the R Foundation for Statistical Computing). Box plots were used to display a set of data. The upper edge of the box indicates the third quartile of the data, and the lower edge indicates the first quartile. The difference between the third and the first quartiles is known as the interquartile range. The bold line in the box indicates the second quartile (median value of the data). The ends of the whiskers represent the lowest value, which is still within 1.5 interquartile range of the first quartile, and

Figure 3 — Participant positioning during biomechanical measurements.
the highest value, which is still within 1.5 interquartile range of the third quartile. The normality of the distributions of all examined variables was examined with the Shapiro-Wilk test. Significant differences between pre- and posttraining data were detected with the Wilcoxon signed-rank test. The percentage increase between the first and second measurements of torque and power was calculated for each group. Significant differences in the percentage increase in all groups were verified using the Kruskal-Wallis test, while significance of the between-groups differences was determined using the Wilcoxon test. Statistical significance was defined at \( p \leq 0.05 \).

**Results**

All subjects tolerated the training well, with the exception of delayed-onset muscle soreness, which was reported by women at the beginning of the training; no other complaints were reported. The maximal torque developed by the dominant arm in the 0-kg and 5-kg groups and by the nondominant arm in the 0-kg group was significantly greater \( (p \leq 0.05) \) after 4 weeks of inertial training (Figure 4). The maximal power developed by the dominant and the nondominant arms in the 0-kg and 5-kg groups was also significantly greater \( (p \leq 0.05) \) after training (Figure 5). In the 0-kg group, the percentage increase in torque and power in the dominant arm was also significantly greater than in the 5-kg group \( (p \leq 0.05; \text{Table 2}) \). In the control group, significant changes were not observed after 4 weeks.

*Figure 4* — Maximal torque measured pre- and posttraining for the dominant and non-dominant arms. C = control. *\( p \leq 0.05 \).
Discussion

This study demonstrated that ITMS training is efficacious, independent of applied loads. It indicates that the device we constructed can be a useful tool for strength and power improvement in older adults. It is also noteworthy that significant increases in torque and power were achieved in a relatively short time (only 4 weeks of exercise). Moreover, such great improvements were detected via measurement...
techniques that did not replicate the training process (measurements using ITMS were not possible at this time), and we conjecture that even greater improvements would be observed under specific inertial testing conditions.

Overall, our results are similar or even superior to previous observations (Albert et al., 1994; Onambele et al., 2008; Romero-Rodriguez et al., 2011; Seynnes et al., 2007; Tesch et al., 2004). However, it should be noted that the training programs in those experiments were longer in duration than in our study, and only Onambele et al. tested older adults. They observed a 28% increase in power achieved by the knee extensors under isokinetic conditions in older women after 12 weeks of training on YoYo ergometers. Albert et al. noted significant improvements (4.9–26.9%) in maximal torque of the biceps brachii in young subjects after 5 weeks of inertial training with the Impulse training system. However, Albert et al. also observed a decline in peak torque in concentric and eccentric movements of 60% for right arms. Seynnes et al. and Tesch et al. reported significant increases in the maximal voluntary contraction of the knee extensors after five weeks of training on YoYo ergometers in young and middle-aged subjects (38.9% and 11.5%, respectively). In addition, an improvement in the maximal eccentric force (obtained on the YoYo leg-press device) after 6 weeks of inertial training was previously noted in young men (Romero-Rodriguez et al., 2011).

The small number of investigations concerning the inertial training of older adults induced us to compare our observations with the effects of other types of strength training. It is noteworthy that training periods in previous investigations lasted much longer than the training period in our study. Valour, Rouji, and Pousson (2004) reported significant increases (11–19%) in maximal voluntary contraction, maximal torque, and maximal power of the elbow flexors in older women after 7 weeks of eccentric training. LaRoche, Roy, Knight, and Dickie (2008) detected a significant increase (12%) in maximal torque of the knee extensors in older women after 8 weeks of explosive resistance training. The experiments of Gur, Cakin, Akova, Okay, and Kucukoglu (2002) revealed gains in peak torque of the knee-extensor and -flexor muscles after 8 weeks of concentric and combined concentric-eccentric isokinetic training in subjects age 41–75 years. Furthermore, Cannon, Kay, Tarpenning, and Marino (2007) reported a significant improvement (18%) in peak isometric torque for the knee extensors after 10 weeks of resistance training in older women. Similar results were obtained by Reeves, Narici, and Maganaris (2006), who observed that older adults (age 65–81 years) significantly increased their maximal isometric (9%) and concentric torque (22–37%) for knee extensors after a 14-week resistance-training period. Wallerstein et al. (2012) noticed an improvement in maximum ramp isometric strength (17.1–22.3%) in people age 60–80 after 16-week strength- and power-training protocols.

The results of several previous studies showed that strength and power training can reduce the negative effects of aging and maintain functional capacity (Hunter et al., 2004; Persch et al., 2009). Since training with the ITMS elicited substantial improvements in maximal mechanical muscle function, it is possible that this regimen can indirectly contribute to better quality of life. However, confirmation of this hypothesis requires further study.

Both training groups in our investigation experienced significant improvements in torque and power, but greater improvement (measured in percentage) was noticed in the 0-kg group (Table 2). This observation suggests that to improve
muscle strength and power in older women, ITMS training should be performed with small loads and probably with high-velocity movements.

However, it should be remembered that results from this study pertain only to loads of 0 and 5 kg, and it is uncertain whether the use of other loads would yield the same outcome. It would also be interesting to determine whether ITMS training is efficacious for other muscle groups. Further study is required.

Lack of special computer software prevented us from registering the range of motion, force achieved during each phase of movement, power, and duration of the movement cycle, while lack of computer registration prevented direct outcome measurement via the ITMS. This software is currently being creating and tested. In the future, we also intend to employ electromyography to assess neuromuscular changes after training.

Conclusions

Short-term training using the ITMS is efficacious and can be used in older women to improve strength and power. ITMS-training-induced changes in older women are greater after the application of smaller external loads.

References


