The Effects of a Water-Based Exercise Program on Strength and Functionality of Older Adults

Paulo Cesar Barauce Bento, Gleber Pereira, Carlos Ugrinowitsch, and Andre L.F. Rodacki

Objective: To analyze the effects of a water-based exercise program on peak torque (PT) and rate of torque development (RTD) during maximal voluntary ballistic isometric contractions of the lower limb muscles and the performance of a number of functional tests in the elderly. Method: Thirty-seven elderly were randomly assigned to water-based training (3 d/wk for 12 wk) or a control group. Extensor and flexor PT and RTD of the ankle, knee, and hip joints and functional tests were evaluated before and after training. Results: PT increased after training for the hip flexors (18%) and extensors (40%) and the plantar-flexor (42%) muscles in the water-based group. RTD increased after training for the hip-extensor (10%), knee-extensor (11%), and ankle plantar-flexor (27%) muscles in the water-based group. Functional tests also improved after training in the water-based group (p < .05). Conclusion: The water-based program improved PT and RTD and functional performance in the elderly.

Keywords: elderly, aging, physical activity

Aging is characterized by neuromuscular changes that include a marked decline in the net joint torque (Delmonico et al., 2009; Frontera et al., 2000), power-production capacity (Candow & Chilibeck, 2005), and resistance to fatigue (Petrella, Kim, Tuggle, Hall, & Bamman, 2005). In general, the muscle-capacity reductions are related to a decrease in the number of fast-twitch fibers and their cross-sectional area (Lexell & Taylor, 1991). Furthermore, some authors have suggested that the ability of older individuals to perform a number of daily tasks (e.g., standing up and climbing stairs) is closely related to the torque-production capacity of the lower limb joints (Hortobágyi, Mizelle, Beam, & DeVita, 2003; Misch, Rosengren, Woods, & Evans, 2007; Narici, Maganaris, Reeves, & Capodaglio, 2003).

Decreases in the muscles’ ability to generate torque around a joint have been associated with a greater risk of falls in the elderly. Indeed, one in three elderly over 70 years of age experience at least one fall per year (Hill & Schwarz, 2004;
“Guideline for the Prevention of Falls,” 2001; Masud & Morris, 2001; Perracini & Ramos, 2002). In addition, some authors have suggested that the ability to produce torque rapidly (i.e., the rate of torque development) is equally important to an adequate response to counteract an external perturbation (e.g., slips and trips) and reestablish body balance (Bento, Pereira, Ugrinowitsch, & Rodacki, 2010). Accordingly, elderly with falls history have presented a lower peak torque and rate of torque development than their counterparts with no falls history (Bento et al., 2010; Pijnappels, Van der Burg, Reeves, & Van Dieën, 2008). Thus, resistance-exercise programs aiming to increase joint torque production and the rate of torque development have been used to decrease the risk of falls.

Decreases in the risk of falls have been reported after both moderate- (Kalapotharakos, Michalopoulos, Tokmakidis, Godolias, & Gourgoulis, 2005) and high-intensity (Frontera, Meredith, O’Reilly, Knuttgen, & Evans, 1988; Kalapotharakos et al., 2005; Persch, Ugrinowitsch, Pereira, & Rodacki, 2009) resistance training that increased muscle-force-production capacity. Furthermore, resistance training has been shown as an effective countermeasure to the marked decline in the rate of force development that has been observed in elderly (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002). Even though resistance-training programs are able to decrease the risk of falls (Persch et al., 2009) and have high adherence (Cyarto, Brown, & Marshall, 2006), identifying alternative training protocols is important for individuals who do not enjoy participating in these type of programs.

Hence, water-based exercises can be an alternative for individuals in preventive and rehabilitative interventions, as they have been considered suitable for patients with special health needs, as well as the elderly (Pöyhönen et al., 2001). However, some reports have shown no improvements in muscle-force-production capacity after water-based exercises in the elderly (Taunton et al., 1996). On the other hand, water-based exercises have been reported as effective in improving isometric, isotonic, and isokinetic strength in young women (Petrick, Paulsen, & George, 2001; Pöyhönen et al., 2002). Thus, the water-based programs used so far have provided controversial results about the ability to increase torque production around the joints.

Tsourlou, Benik, Dipla, Zafeiridis, and Kellis (2006) reported increased knee-extensor and -flexor torques in the elderly after a water-based program. Nonetheless, they used specific water-resistance training devices to increase training load. Another interesting strategy to impose a higher stress to the muscle tissue is increasing movement speed. The opposing water resistance to the movement is proportional to the square of movement speed, which may also provide an appropriate stimulus to improve muscle-force-production capacity. Thus, an exercise program that combines the use of water-resistance training devices and high movement speed may increase torque-production capacity in older individuals. In addition, this combination may be effective in increasing the rate of torque development, which is an important adaptation that has not been described in the sport sciences literature. We hypothesized that the peak torque and the rate of torque development of elderly subjects could be improved after a water-based-exercise training period that combines the use of water-resistance devices and fast movement speeds.

Therefore, the aim of the current study was to analyze the effects of a water-based program on peak torque and rate of torque development during a maximal voluntary isometric contraction (MVIC) of the muscles around the hip, knee, and
ankle joints. We also aimed to determine if a water-based program could modify the performance of a number of functional tests in a group of elderly individuals.

**Methods**

**Participants**

Thirty-seven volunteers living in the community near the Federal University of Paraná and able to walk and perform their daily tasks independently volunteered to participate. Participants were contacted using the local media, and flyers. They received details about aims and protocols involved in the study. Volunteers who had engaged in other systematic physical activity programs during the 6 months that preceded the study were not included. A physician screened the volunteers for health problems (e.g., heart conditions, general health problems) and restrictions to exercise in the water (e.g., skin problems, orthopedic conditions). Procedures were granted approval by the ethics committee of the Federal University of Paraná.

**Measurements**

Participants visited the laboratory on five occasions. On the first visit, they answered a questionnaire designed to determine their physical activity level (NAF, version 8; Benedetti, Mazo, & Barros, 2004). Then, they were assigned to either the water-based training group (WBG; \( N = 24 \); 65.6 ± 4.2 years old, range 60–73; 75.4 ± 15.35 kg; 157.6 ± 7.5 cm) or the control group (CG; \( N = 14 \); 65.6 ± 4.4 years old, range 61–76; 74.2 ± 11.9 kg; 159.1 ± 9.3 cm), based on their physical activity level. The WBG comprised 16% male and 84% female participants, while the CG included 28% and 72%, respectively. The participants were classified in quartiles according to their physical activity level and randomly assigned to each experimental or control group. This procedure was performed to reduce the chances of having unbalanced groups (Persch et al., 2009). The physical activity analysis of the participants revealed the following levels: 56% very active, 21.8% active, 15.6% moderately active, and 6.2% sedentary. In the next session, they performed a series of functional tests that included the 6-min-walk, the sit-and-reach, the 8-ft up-and-go, and the 30-s chair-stand tests (Rikli & Jones, 1999a). A rest interval of 10 min was allowed between tests to avoid pronounced fatigue effects. In the third and fourth sessions, a familiarization protocol with the MVIC test was conducted, where three to five trials per test were allowed. In the fifth session (48 hr after fourth session), the MVIC test of the dominant lower limb was performed. Figure 1 represents the experimental design of the study.

**MVIC**

Hip-, knee-, and ankle-flexion and -extension MVIC torques were assessed in a recumbent posture where proximal segments were firmly secured and stabilized by a Velcro strap while tested segments were positioned at approximately 90° (Persch et al., 2009). The tests followed a reversed balanced order—the order followed by one participant was followed in a reversed order by the next one. Force–time traces were determined with a load cell (Model CZC500, Kratos, São Paulo, Brazil) firmly
Figure 1 — Schematic representation of participant recruitment and allocation.
attached to an adjustable pole that permitted aligning the line of pull perpendicularly to the dominant (tested) segment. An adjustable cuff was used to secure the cable to the tested segment. The perpendicular distance between the load cell and the joint center was determined and used to calculate net joint torques. Participants were instructed to produce torque as fast and hard as possible and to sustain the contraction for approximately 2–3 s. The peak torque obtained in the three maximal trials was used for further analysis. Each maximal trial was followed by a 1-min rest. Figure 2 provides a schematic representation of the torque-testing procedures.

The force–time signals were sampled with a frequency of 1 kHz, amplified (Kratos, model IK-1C, São Paulo, Brazil), converted to digital signals with the aid of a 16-bit A/D card (National Instruments, model NI USB 6218, USA), and stored on a personal computer. Raw torque data were low-pass filtered with a Butterworth second-order recursive filter set at 20 Hz. Peak torque was determined as the highest torque value obtained after the onset of the voluntary contraction. The rate of torque development was defined as the slope of the force–time curve from 20% to

![Figure 2](image_url) — Schematic representation of the position of the line of pull and participant’s position during the peak-torque and rate-of-torque-development tests (adapted from Bento et al., 2010).
80% of the peak-torque values. The coefficient of determination was calculated to assess the fit of the regression equations \((R^2 = .98)\). Both variables were calculated using a customized routine (Matlab 6.0, USA).

**Interventions**

The water-based program was performed for 12 weeks, three times per week (60 min/session). Water level was kept at the xiphoid process, and the temperature, at 28–30 °C. Each session included a 10-min warm-up, 20 min of aerobic activities, and 20 min of specific lower limb strength exercises (20 min). Stretching exercises were performed in the last 10 min of the session as a cooldown activity.

The aerobic activities comprised the following exercises: long-lever pendulum-like movements of the lower extremities; forward and backward jogging with arms pushing, pulling, and pressing; and leaps, kicks, leg crossovers, and hopping movements focusing on traveling in multiple directions. Exercise intensity was controlled using the rate of perceived exertion (RPE; 12–16 on the 15-point Borg scale [6–20 points]) and heart rate (progressing from 40% to 60% of the heart-rate reserve), according to the American College of Sports Medicine’s (2009) recommendations. These exercises were maintained during the final 4 weeks, but exercises without the feet contacting the bottom of the pool were also included in an attempt to increase exercise intensity.

The strength activities involved hip and knee flexion and extension and dorsal and plantar-flexion of the ankle (knee extension–flexion, hip extension–flexion and adduction–abduction with extended knee, double knee lifts, and side press kicks) while holding on the pool edge (Tsourlou et al., 2006). These exercises were performed for 40 s with a rest interval of 20 s at a moderate speed, at an RPE of 12 during the first 4 weeks. For Weeks 5–8, intensity was increased by augmenting movement speed and by including water-resistive devices (RPE or 12–14). Finally, during the last 4 weeks, exercises were performed with the highest voluntary speed (RPE 14–16). Mean attendance at training sessions was 94%. The CG was required to maintain their regular habits and refrain from unusual physical activities during the period of the study, but they were invited to engage in the program at the end of the experimental period. Participants of the CG confirmed at posttest that they maintained their physical activity levels during the period of the study.

**Data Analysis**

The Shapiro–Wilk test confirmed data normality of most variables. Variables without normal distribution were transformed to logarithm values. The knee flexors’ peak torque and rate of torque development were analyzed using the Kruskall–Wallis test because it was not possible to normalize the data after transforming. A two-way repeated-measures analysis of variance (ANOVA) was applied to determine if training (independent variable) was effective in changing peak torque and rate of torque development of the lower limb joints and functional-test performance (i.e., 6-min walk, sit-and-reach, 8-ft up-and-go, and the 30-s chair-stand) as dependent variables. Time (i.e., pre- and postassessment) was considered a repeated factor. An initial analysis using a one-way ANOVA revealed between-groups differences in the initial values. Then, pretest values were used as covariates to compare posttest
values, disregarding the pretraining differences. Tukey’s post hoc test was used for multiple-comparison purposes in case of significant $F$ values. All statistical analysis were performed using Statistica Software (StatSoft, version 7, USA), and the significance level was set at $p < .05$.

**Results**

The statistical analysis revealed no differences in age and physical characteristics between groups ($p > .05$). Peak torque, rate of torque development, and functional tests were also similar between groups before the exercise-training program, except for the hip flexors’ torque and the knee extensors’ rate of torque development.

Tables 1A and 1B present values for peak torque and rate of torque development around the hip, knee, and ankle joints in the pre- and posttest assessments for the WBG and CG. A peak-torque increase ($p < .05$) was detected for the hip flexors and extensors and for the plantar-flexor muscles after training in the WBG. The peak torque of the knee extensors and flexors and ankle dorsiflexors did not differ between groups in the posttraining assessment ($p > .05$). The rate of torque development increased in the hip extensor, knee extensor, and ankle plantar flexors ($p < .05$) but remained unchanged in other muscle groups after training ($p > .05$). No changes ($p > .05$) were found in the CG.

Functional data are presented in Table 2. After training, participants showed improved performance in the sit-and-reach test. The time in 8-ft up-and-go test decreased, while the distance in the 6-min test increased ($p < .05$). No changes ($p > .05$) were observed in the chair-stand test after training.

**Discussion**

The main finding of the current study was that a 12-week moderate-intensity water-based training program was able to improve the ability of the muscles to produce torque (peak torque) at a high velocity (rate of torque development). In addition, participants presented improved performance on most of the functional tests.

It is difficult to compare the strength gains reported herein with those of other studies, as there is scarce evidence on the effects of water-based training programs in the elderly. So far, Tsourlou et al. (2006) conducted the only study that reported peak-torque increases of 10.5% and 13% around the knee-extensor and -flexor muscles, respectively, after 24 weeks of water-based training using water-resistance training devices. The current study found comparable, but nonsignificant, torque increases for these muscle groups (14% and 12%, respectively). However, it must be emphasized that participants only trained for 12 weeks in our study. Thus, it is possible that the combination of using water-resistance training devices and high movement speed provided additional mechanical stimuli that elicited earlier strength gains.

A novel finding of the current study was a large change in peak torque of the hip extensors and flexors after training, in which torque gains in the extensors were more than 2 times greater than observed in the flexors (40% vs. 18%, respectively). As most body displacements during training sessions were performed at high speed, the resistive forces created by the water during thigh movements may
Table 1A  Peak Torque ($M \pm SD$) Around the Hip, Knee, and Ankle Joints Before and After the Training Program

<table>
<thead>
<tr>
<th>Joint</th>
<th>Experimental Group</th>
<th>Control Group</th>
<th>$F(1, 35)$</th>
<th>p</th>
<th>ES (Cohen’s $d$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td></td>
</tr>
<tr>
<td>Hip extension</td>
<td>107.3 ± 35.0</td>
<td>150.0 ± 48.4*</td>
<td>113.9 ± 45.7</td>
<td>110.8 ± 37.5</td>
<td>20.20 .00 .46</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>45.64 ± 10.1</td>
<td>53.9 ± 12.3*</td>
<td>57.9 ± 17.4</td>
<td>51.8 ± 15.0</td>
<td>6.05 .01 .06</td>
</tr>
<tr>
<td>Knee extension</td>
<td>73.9 ± 28.0</td>
<td>84.4 ± 40.6</td>
<td>78.1 ± 24.8</td>
<td>76.5 ± 32.2</td>
<td>3.22 .08 .12</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>30.1 ± 12.7</td>
<td>33.7 ± 14.8</td>
<td>30.1 ± 10.5</td>
<td>30.4 ± 9.8</td>
<td>0.45 .50 .16</td>
</tr>
<tr>
<td>Plantar flexion</td>
<td>22.4 ± 9.3</td>
<td>31.9 ± 13.3*</td>
<td>21.6 ± 6.0</td>
<td>22.0 ± 6.2</td>
<td>18.10 .00 .62</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>16.6 ± 7.0</td>
<td>19.4 ± 7.3</td>
<td>14.9 ± 4.3</td>
<td>15.3 ± 3.9</td>
<td>1.67 .20 .46</td>
</tr>
</tbody>
</table>

Note. $F$ and $p$ values refer to interaction differences.

* Significant time effect (pre vs. post) differences at $p < .05$. 
Table 1B  Rate of Torque Development (\(M \pm SD\)) Around the Hip, Knee, and Ankle Joints Before and After the Training Program

<table>
<thead>
<tr>
<th>Rate of Torque Development, N (\cdot) m(^{-1}) (\cdot) s(^{-1})</th>
<th>Experimental Group</th>
<th>Control Group</th>
<th>(F(1, 35))</th>
<th>(p)</th>
<th>ES (Cohen’s (d))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td></td>
</tr>
<tr>
<td>Hip extension</td>
<td>558 ± 504</td>
<td>613 ± 383*</td>
<td>562 ± 392</td>
<td>345 ± 209</td>
<td>5.51</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>315 ± 192</td>
<td>314 ± 158</td>
<td>442 ± 295</td>
<td>310 ± 144</td>
<td>1.66</td>
</tr>
<tr>
<td>Knee extension</td>
<td>255 ± 144</td>
<td>283 ± 171*</td>
<td>310 ± 150</td>
<td>263 ± 113</td>
<td>5.66</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>157 ± 80</td>
<td>188 ± 137</td>
<td>212 ± 100</td>
<td>171 ± 83</td>
<td>0.18</td>
</tr>
<tr>
<td>Plantar flexion</td>
<td>95 ± 59</td>
<td>121 ± 62*</td>
<td>96 ± 41</td>
<td>77 ± 65</td>
<td>9.11</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>60 ± 34</td>
<td>75 ± 36</td>
<td>67 ± 38</td>
<td>57 ± 24</td>
<td>2.63</td>
</tr>
</tbody>
</table>

Note. \(F\) and \(p\) values refer to interaction differences. *Significant time effect (pre vs. post) differences at \(p < .05\).

Table 2  Functional-Test Performance (\(M \pm SD\)) of the Experimental and Control Groups Before and After the Training Program

<table>
<thead>
<tr>
<th>Functional-Test Performance</th>
<th>Experimental Group</th>
<th>Control Group</th>
<th>(F(1, 35))</th>
<th>(p)</th>
<th>ES (Cohen’s (d))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td></td>
</tr>
<tr>
<td>30-s chair stand (reps)</td>
<td>13.79 ± 2.85</td>
<td>14.58 ± 2.10</td>
<td>12.30 ± 1.88</td>
<td>12.23 ± 1.36</td>
<td>0.01</td>
</tr>
<tr>
<td>Sit-and-reach (cm)</td>
<td>–1.7 ± 10.82</td>
<td>5.29 ± 11.94*</td>
<td>–3.11 ± 14.95</td>
<td>–1.7 ± 15.68</td>
<td>9.80</td>
</tr>
<tr>
<td>8-ft up-and-go (s)</td>
<td>5.54 ± 0.80</td>
<td>5.12 ± 0.46*</td>
<td>5.18 ± 0.85</td>
<td>5.28 ± 0.50</td>
<td>5.30</td>
</tr>
<tr>
<td>6-min walk (m)</td>
<td>572.7 ± 75.1</td>
<td>596.8 ± 77.1*</td>
<td>585.4 ± 79.4</td>
<td>558.3 ± 79.4</td>
<td>14.80</td>
</tr>
</tbody>
</table>

Note. \(F\) and \(p\) values refer to interaction differences. *Significant time effect (pre vs. post) differences at \(p < .05\).
explain the difference in peak-torque increase (Pöyhönen et al., 2002). Fast movements performed in the water are thought to increase the displacement resistance in a quadratic order, thereby imposing a considerable opposing force (i.e., total drag forces) to the movement of the lower segments (Becker, 2000; Pöyhönen et al., 2002; Skinner & Thomson, 1985).

The hip-extensor muscles also showed an important increase in the rate of torque development. The influence of the water-based training program on the ability to generate torque rapidly can be explained by the fact that walking and exercising in the water require larger torques to propel the body forward (Miyoshi, Shirota, Yamamoto, Nakazawa, & Akai, 2005; Nakazawa, Yamamoto, & Yano, 1994). Masumoto, Takasugi, Hotta, Fujishima, and Iwamoto (2004) and Masumoto et al. (2007) measured muscle activation during walking in the water and observed increases in electromyography up to 150% during walking at fast speeds in comparison with the values at slow walking speed, which may explain the gains observed after exercising in the water using fast movements. In addition, Barela, Stolf, and Duarte (2006) reported a positive-only component of the anteroposterior vector of the ground-reaction force during the stance phase, which indicates a strategy to counteract the large frontal water resistance to body displacement while walking in the water. As the knee is slightly more extended in water than on dry land during the early stance phase, a larger contribution of the opposite hip-extensor and ankle plantar-flexor muscles may be required to propel the body up and forward. The larger contribution of the hip-extensor muscles in water displacements may explain the larger gains in peak torque and rate of force development than in the hip-flexor muscles. On the other hand, the hip-flexor muscles may have had water-lifting forces that helped bring the segment toward the surface (i.e., an upward thrust), which reduced the torque and rate of torque development required to flex the hip joint and elevate the lower limb during the swing phase and forward displacements in the water. Increased peak torque and rate of torque development were also observed in the plantar-flexor muscles and can be explained by the greater excursion of the ankle joint (Barela et al., 2006) needed to produce the positive-only impulse observed during walking in the water.

It has been proposed that the plantar-flexor muscles are responsible for generating a large propulsive impulse at the end of the stance phase (Kerrigan, Lee, & Collins, 2001). This impulse acts to increase the upward forces that rise and rotate the hip to improve pelvic gait (Cristopoliski, Barela, Leite, Fowler, & Rodacki, 2009). In fact, a larger plantar-flexion range of motion and a greater activation of the gastrocnemius muscle group may have contributed to the continuous push-off forces (anteroposterior force component) observed during the final stance phase during walking in the water (Barela et al., 2006). Placing the foot on the ground is mandatory to perform several movements required in the exercise routine performed in the water and may have imposed a large demand around the ankle that elicited important muscle-strength improvements (Katsura et al., 2010). It has been suggested that ankle stability is a contributing factor to lower extremity performance and risk of fall (Katsura et al., 2010; Maki, 1997; Suzuki, Bean, & Fielding, 2001).

The knee-flexor and -extensor muscles’ torque-production capacity (peak torque and rate of torque development) did not show a large change after the water-based training program, except for the rate of torque development of the knee-extensor muscles. Miyoshi et al. (2005) measured joint moments during
walking on water and observed that the late knee-extension moment presented a small increase but had no significance at fast walking speeds. They concluded that the function of knee-joint moment is to absorb impact forces during gait. As impact forces are smaller while walking and exercising in the water than on dry land, the nonsignificant increases in peak torque and rate of force development in the knee-extensor muscles are not surprising. In addition, the size and the shape of the distal segments of the lower limbs (leg and foot) are relatively small (Becker, 2000; Skinner & Thomson, 1985) and may have created a weak training stimulus that was unable to promote significant strength gains, despite the use of devices to increase water resistance (i.e., aquafins) and the high movement speed used while exercising in the water.

Baseline scores of the functional tests were compatible with normative values for older individuals (Rikli & Jones, 1999b). Thus, improvements in the WBG can be attributed to the exercise program, as muscle function improved (peak torque and rate of torque development). In addition, no changes in muscle function or functional tests were observed in the CG. These findings reinforce the relevance of lower extremity muscle-force-production capacity to reduce functional limitations in the elderly (Steib, Schoene, & Pfeifer, 2010).

Alves, Mota, Costa, and Alves (2004) analyzed the effects of a 12-week exercise program performed in the water and found significant improvements in the chair-stand, seat-and-reach, 6-min-walk, and 8-ft up-and-go tests similar to those in the current study. The sit-to-stand test was the only functional test that did not change after training. Hip (Pai & Rogers, 1991) and ankle plantar and dorsiflexion (Suzuki, Bean, & Fielding, 2001) strength have been described as important factors to chair-rise performance; however, the knee extensors’ torque contribution is also an essential requirement, especially when movement speed increases (Pai & Rogers, 1991). Hughes, Myers, and Schenkman (1996) showed that the torque required to rise from a chair demands a large knee-extensor strength (~80% of maximal capacity) in the functionally impaired elderly. It has been suggested that older adults execute activities of daily living while exerting nearly maximal torque-producing capabilities of the knee joint (Hortobágyi et al., 2003). Thus, the low effectiveness of the water-based exercise program to improve the torque of the knee-extensor muscles may partially explain the unchanged results of the sit-to-stand test (Hortobágyi et al., 2003; McCarthy, Horvat, Holsteberg, & Wisenbaker, 2004).

The reduced time to perform the 8-ft up-and-go test is generally attributed to improvements in dynamic balance and agility (Alves et al., 2004; Tsourlou et al., 2006). These gains can be partially explained by the resistance and balance disturbance caused by the water turbulence produced during the exercises (Douris et al., 2003; Melzer, Elbar, Tsedek, & Oddsson, 2008), especially when changes in the direction of displacements are included in the exercise routines. The short period demanded to exert large amounts of torque while exercising in the water may have provided a stimulus capable of improving functional response.

The training program was designed to exercise large muscle groups at moderate intensity and fast speed, which was effective to promote discrete, but significant, improvements in the older adults’ aerobic fitness, as revealed by the increased distance in the 6-min-walk test. Takeshima et al. (2002) also reported oxygen-consumption improvements in response to a 12-week water-based program executed three times per week, in which 30 min were devoted to aerobic conditioning. Thus,
it seems that water-based exercise programs are effective in improving aerobic fitness in the elderly.

Improvements in the 6-min-walk test may also be attributed to gains in the rate of torque development that were observed in almost all joints activated while walking, as demonstrated by Cuoco et al. (2004), who showed that walking tasks are more velocity dependent than strength dependent. On the other hand, the similarities between the exercises included in the water-based routines and the functional tests may have facilitated the transfer from training to everyday tasks (Barry & Carson, 2004).

Sit-and-reach-test improvements were comparable to those described by Alves et al. (2004) and Tsourlou et al. (2006). These gains can be attributed to water’s effect on the joints’ range of motion. Indeed, frontal and lateral kicking movements demand greater joint range of motion around the lower extremity joints than a dry-land condition. A more detailed range-of-motion assessment is required to determine whether a water-based training program influences other segments of the lower limb.

Conclusions

The results of the current study provide evidence that water-based training program is effective in improving peak torque in the hip extensors, hip flexors, and plantar flexors and rate of torque development in the hip extensors, knee extensors, and plantar flexors, which were translated into improved functional performance, being effective at reducing or reversing some muscular age-related declines. Water-based training programs are an attractive way not only to exercise safely but also to keep elderly individuals active. The muscle-function gains observed in this study may be attributed to the emphasis on movement speed, using water properties to impose exercise resistance. The fast nature of the movements performed in the water may constitute a more specific training stimulus to improve functional performance, which may be more dependent on the rate of torque development than strength gain, although the latter can also be achieved by a water-based training program. Therefore, water-based exercise programs constitute an attractive strategy to improve muscle capacity and functionality and reduce the risk of falls in older adults.

Acknowledgment

We thank Dr. Luiz Cesar da Veiga Pessoa for his time screening the health status of the participants of the study.

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