Exercise Improves Video Game Performance: A Win–Win Situation

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ABSTRACT

DE LAS HERAS, B., O. LI, L. RODRIGUES, J.-F. NEPVEU, and M. ROIG. Exercise Improves Video Game Performance: A Win–Win Situation. Med. Sci. Sports Exerc., Vol. 52, No. 7, pp. 1595–1602, 2020. Purpose: Video gamers exceeding screen-time limits are at greater risk of experiencing health issues associated with physical inactivity. Demonstrating that exercise has positive effects on video game performance could promote physical activity among video gamers. We investigated the short-term effects of a single session of cardiovascular exercise on the performance of the popular video game League of Legends (LoL) and explored psychosocial mechanisms. Methods: Twenty young video gamers played a customized LoL task preceded by a short bout of high-intensity interval training or a period of rest. The two conditions were administered on two separate days in a randomized counterbalanced fashion. Video game performance was assessed as the total number of targets eliminated as well as accuracy, defined as the ability to eliminate targets using single attacks. Short-term changes in affect after exercise as well as exercise enjoyment were also assessed. Results: Exercise improved (P = 0.027) the capacity to eliminate targets (mean ± SEM, 121.17 ± 3.78) compared with rest (111.38 ± 3.43). Exercise also enhanced accuracy (P = 0.019), with fewer targets eliminated with more than one attack after exercise (1.39 ± 0.39) compared with rest (2.44 ± 0.51). Exercise increased positive affect by 17% (P = 0.007), but neither affect nor exercise enjoyment was associated with total number of targets eliminated or accuracy. Conclusion: A short bout of intense cardiovascular exercise before playing LoL improves video game performance. More studies are needed to establish whether these effects are generalizable to other video games, whether repeated bouts have summative effects, and to identify underlying mechanisms.

Key Words: SCREEN TIME, CARDIOVASCULAR EXERCISE, ENJOYMENT, EXECUTIVE FUNCTION, GAMING

There are 2.3 billion video game players in the world, and this number will rise to 2.7 billion by 2021 (1). In the United States alone, the video game industry is expected to generate revenues exceeding $90 billion by 2020 (2). Online video game platforms such as League of Legends (LoL) or Fortnite gather monthly 67 and 78.3 million players, respectively. Events such as the 2018 LoL World Championship were watched by more than 200 million viewers, setting a new bar in the history of video games and surpassing global events like the Super Bowl (103.4 million viewers) (3). Video gaming is becoming a professional activity, with top players participating in major video game tournaments earning salaries comparable with superstar athletes (4). Despite the potential benefits of video gaming (5), there is a growing concern with the long-term health status of people exposed to this new form of entertainment (6).

Screen time has traditionally been associated with lower physical activity levels (7,8). Video game screen time, specifically, has been associated with reduced physical activity and an increased risk of being overweight (9,10), although the effects on the latter are possibly small (11). Physical inactivity, in turn, has shown to increase the risk of developing cardio-metabolic clinical conditions such as hyperlipidemia, coronary heart disease, and diabetes (12). With the exception of active video games, most video games require minimal body movement and energy expenditure and are usually played in a seated position (13). This is crucial because excessive sitting time has been linked with poor cardiometabolic health, even in people who meet recommended physical activity levels (14). Gamers exceeding screen time are therefore at a higher risk of experiencing long-term cardiometabolic health problems (15).

Cardiovascular exercise improves overall health and reduces the risk of developing sedentary-related cardiometabolic health problems (16). Importantly, this exercise modality has also shown to have positive effects on cognition (17). The cognitive functions most susceptible to improve as a result of cardiovascular training are those involved in executive-control...
processes, which require filtering redundant or incongruent information and/or making fast and accurate decisions (18). Because executive-control processes are actively engaged during the practice of most video games (5,19), one could expect that the cognitive gains derived from the practice of cardiovascular exercise could also lead to improvements in video game performance. However, direct scientific evidence supporting the link between cardiovascular exercise and video game performance is still to be established.

The beneficial effects of cardiovascular exercise on cognition are mediated by neurobiological mechanisms. This type of exercise triggers the release of several neurochemicals and signaling molecules, which can potentially promote changes in discrete areas of the brain to optimize different aspects of cognitive processing (20). However, this type of exercise has also shown to improve different aspects of psychosocial well-being, which could also influence cognitive health. For example, cardiovascular exercise performed regularly confers protection against the devastating and pervasive effects that stress and anxiety have shown to have on different aspects of cognition (21). Importantly, heavy video game players appear to be at a higher risk of depression and other psychosocial alterations (22). Determining whether the individual psychosocial response to exercise (e.g., affect, enjoyment) influences the effects of exercise on video game performance could improve exercise prescription in this population (23). For example, this information could be used to identify which video gamers, based on their psychosocial response to exercise, are more or less responsive to the effects of this intervention on video game performance.

We investigated the short-term effects of cardiovascular exercise on the performance of LoL. This popular video game (https://oce.leagueoflegends.com/en/) allows the design of customized practice tasks, which can be used to assess different aspects of game performance using standardized experimental procedures. We used a single bout of exercise because this exercise paradigm is ideally suited to study time-dependent effects of exercise on cognition (24) and, more importantly, because we wanted to determine whether even a very short session of exercise can have positive effects on video game performance. Acute cardiovascular exercise has shown to be very effective in enhancing the performance of cognitive tasks, which rely on the same executive-control processes (25) that effective in enhancing the performance of cognitive tasks, which rely on the same executive-control processes (25) that...
Experimental design. We used a within-subject study design, which comprised three laboratory sessions lasting approximately 1 h each (Fig. 1). The use of this experimental design, in which participants go through all the experimental conditions thus acting as their own controls, allowed us to reduce variability and increase the statistical power of the study (29), while reducing the effect of differences in video game skill level among participants. On session 1, participants underwent an initial evaluation, including cognitive and physical activity assessments as well as a graded exercise test (GXT), to assess cardiorespiratory fitness. On session 2 or 3, participants went through either the exercise or the resting condition. The order of allocation to the two conditions was randomized using https://www.randomizer.org by a person not involved in the testing. At the end of the study, half of the participants performed the exercise condition on session 2 and half of the participants on session 3. In this way, the two conditions were administered in a counterbalanced order, thus minimizing any potential carryover effect between the two experimental sessions. Twenty minutes after exercise or rest, participants played 20 min of a customized LoL task (see description below).

Importantly, participants had to do the GXT (session 1) between 7 and 2 d before session 2. This was done to make sure that the data of the GXT were still valid to individually tailor the intensity of the exercise intervention during session 2 or 3 (see exercise section) but also to reduce any potential influence of the GXT on session 2. Participants were also asked not to exercise the day before sessions 2 and 3. Similarly, 48 h of separation was kept between sessions 1 and 2, and neither exercise nor playing video games between these two last sessions was allowed. Seven days after session 3, participants were contacted via telephone and were asked questions regarding their self-perceived enjoyment when undertaking cardiovascular exercise (see enjoyment section). All procedures were approved by our local ethics review board (CRIR-1388-0119).

Initial evaluation. Cognitive status was assessed with the National Institutes of Health (NIH) cognitive toolbox (http://www.nihtoolbox.org). The NIH cognitive toolbox is a well-validated and psychometrically robust comprehensive set of neurobehavioral tests that assess the following cognitive functions: attention (flanker inhibitory control and attention tests), executive functioning (flanker inhibitory control and attention and dimensional change card sort test), episodic (picture sequence test) and working (list sorting test) memory, and speed processing (pattern comparison processing speed test). The NIH toolbox, which is completed on an iPad® in 25–30 min, provides age-corrected normative composite scores for all the aforementioned cognitive tests.

Both physical activity and sitting time were assessed with the self-administered International Physical Activity Questionnaire (IPAQ) long form (30). This version of the IPAQ contains 27 questions that are used to determine the time (minutes) that participants spent in physical activities of different intensity levels in the 7 d before completing the questionnaire. The IPAQ can be completed in 8–10 min and has shown excellent concurrent and construct validity when compared with data obtained with physical activity monitors (30). Handedness was assessed with the Edinburgh Handedness Inventory, a well-validated questionnaire (31), which contains 10 questions to determine to what degree the person is right- or left-handed, and that can be completed in 2–3 min.

GXT. The GXT was performed on a cycle ergometer (Corival, Lode, Netherlands). Oxygen consumption (\(V\dot{O}_2\)) was measured using a Vmax Encore 29C (CareFusion, Franklin Lakes, NJ) metabolic cart. Heart rate (HR) (H10, Polar, Canada) and RPE with the 6–20 Borg scale (32) were monitored continuously. This GXT protocol, which has been used in previous studies with similar populations (28), consists of a 3-min warm-up at a workload of 50 W followed by a gradual workload increase of 30 W every 3 min. Participants maintained a pedaling cadence of \(\geq 80\) rpm until exhaustion. Peak oxygen consumption (\(V\dot{O}_{2\text{peak}}\)), the gold standard measure of cardiorespiratory fitness, was obtained by calculating the \(V\dot{O}_2\) average in the last 30 s of the GXT immediately before exhaustion (28). Maximum HR (HR\(_{\text{peak}}\)) and workload (\(W_{\text{peak}}\)) at each stage were recorded and used to tailor the intensity of the exercise condition for each participant individually. All participants completed the GXT without problems and/or any adverse effects.

FIGURE 1—Experimental phases of the study. The study involved three sessions. On session 1, participants underwent an initial evaluation, including cognitive and physical activity assessments with the NIH Cognitive Toolbox and the IPAQ, respectively. The initial evaluation finalized with a GXT to assess cardiorespiratory fitness. On sessions 2 and 3, participants went through either the exercise or the resting condition. After either condition, participants read a book for 20 min, and then they played 20 min of a customized LoL task.
**Exercise and rest conditions.** The exercise condition consisted of 15 min of high-intensity interval training (HIIT) performed on the same cycle ergometer used for the GXT. HIIT is a highly time-efficient exercise modality, which stimulates powerful adaptations, even when low training volumes are used (33). This time efficiency could potentially be appealing to those video gamers who do not want to devote much time exercising. The intensities during the HIIT were adjusted for each participant, based on the results of the GXT. In short, HIIT started with 2.5 min of warm-up (40% $W_{\text{peak}}$) followed by five 1-min blocks of high-intensity (80%–85% $W_{\text{peak}}$) interspersed with five 1-min blocks of low intensity (40% $W_{\text{peak}}$) in between. The protocol ended with 2.5 min of cooldown performed at 40% $W_{\text{peak}}$. Participants were asked to maintain a cycling cadence of ≥80 rpm. Intensity was monitored with an HR monitor and the RPE (32). In the rest condition, participants sat on the cycle ergometer for 15 min without pedaling. After either condition, participants read a book (Memory, by Alan Baddeley) for 20 min to standardize any external stimulation effect before the assessment of the affective response to exercise and the performance of the video game task.

**Assessment of affect.** At the end of the 20-min reading period after either the exercise or the rest condition, participants were required to fill out the Positive and Negative Affect Schedule Scale (PANAS) (34). This scale was used to determine whether short-term exercise-induced changes in affect influenced video game performance. The PANAS is a self-reported questionnaire that consists of two 10-item scales to measure both positive and negative affect. Each item is scored on a 5-point scale of 1 (not at all) to 5 (very much). The PANAS can be completed in 2 min, and it has shown to be a reliable and valid instrument to assess positive and negative affect (35) in response of acute cardiovascular exercise (28).

**Video game task.** Participants played a customized LoL video game task seated on a chair in front of a computer monitor (see Figure, Supplemental Digital Content 1, for set up of video game task, http://links.lww.com/MSS/B901). They placed their right hand on a mouse that controlled the movements of the video game’s character and launched the attacks. To standardize game options, all participants used the same character, and no ability upgrades or new item purchases were allowed. Designing a customized LoL task allowed us to reduce game performance variability.

The task consisted of 20 min of LoL played individually (see Figure, Supplemental Digital Content 2, for description of the video game task, http://links.lww.com/MSS/B902). Participants were instructed to “eliminate as many targets as possible with a single attack.” They were also told that “targets eliminated with more than one attack would not be counted toward the final score.” The ability to use a single attack effectively is a fundamental skill of experienced LoL players. Eliminating targets in a single attack is rewarded with gold and experience, vital components toward making one’s character stronger.

Video game performance was assessed visually by three independent assessors as the total number of targets eliminated as well as accuracy, defined as the ability to eliminate a target in a single attack. The number of targets eliminated appeared on the right upper corner of the screen. Targets eliminated with more than one attack were counted by the assessors and marked as accuracy errors. Assessing separately the total number of targets eliminated in one attack and the number of errors allowed us to identify potential speed accuracy trade-offs.

Assessors monitored participants throughout the video game task. Participants were notified of the remaining time, 10, 5, and 1 min before the end of the task. Before the experiments, we conducted a pilot study to determine the reliability of the three assessors who scored individually 20 min of an LoL task recorded previously. Interassessor consistency in scoring the task visually was excellent (intraclass correlation coefficient = 1, $P < 0.003$) both for targets eliminated and accuracy errors.

**Assessment of enjoyment.** Seven days after session 3, the participants’ level of enjoyment derived from cardiovascular exercise was assessed via telephone. We aimed to determine whether participants’ perceptions toward cardiovascular exercise affected its effects on video game performance. We assessed enjoyment 7 d after participation in the experiments to minimize the potentially confounding short-term effects of HIIT (36). An adapted version of the Physical Activity Enjoyment Scale, which has shown to have good validity and repeatability (37), was used. Participants responded to the following: “Rate how you feel in general about doing cardiovascular exercises like the one you experienced in our experiment” in relation to eight domains (37) using a 7-point scale (1 = does not make me happy, 7 = makes me happy). Higher scores (min 8 and max 56) indicated greater enjoyment.

**Statistical analysis.** Data were plotted and inspected visually, and normality was confirmed with the Shapiro–Wilk test. Paired $t$-tests were used to assess differences in video game performance (number of targets eliminated in one attack and number of accuracy errors) as well as affective response (PANAS) between the exercise and the rest conditions. Effect sizes were calculated using the Cohen’s $d$ statistic ($d$ = mean difference/SD). Pearson or Spearman’s correlations were used to determine whether individual affect and enjoyment, as well as other individual variables, were associated with the effects of acute exercise on video game performance. To this end, we calculated differences in video game performance (i.e., number of targets eliminated and number of accuracy errors) between the two experimental conditions (exercise–rest) and determined whether the difference was associated with the psychosocial outcomes. Correlations were also used to explore associations between video game performance and LoL rank, cardiorespiratory fitness, physical activity level, and cognitive status. Analyses were performed with a two-tailed probability test, with the statistical level set at $P < 0.05$. Unless otherwise stated, data are provided as mean and SEM.

**RESULTS**

The main physiological and affective responses after each experimental condition are summarized in Table 2. As expected, the average HR$_{\text{peak}}$ and the highest RPE in the rest condition
were significantly lower than those in the exercise condition ($t_{17} = 2.41, P = 0.027, d = 0.57$). In comparison with the rest condition, exercise increased positive affect significantly ($t_{17} = 3.08, P = 0.007, d = 0.73$). By contrast, there were no significant differences in negative affect ($t_{17} = 0.11, P = 0.91, d = 0.02$) between the two conditions. Consistent with our hypothesis, exercise improved significantly ($t_{17} = 2.41, P = 0.027, d = 0.57$) the capacity to eliminate targets (mean ± SEM = 121.17 ± 3.78) compared with rest (mean ± SEM = 111.38 ± 3.43) (Fig. 2). Exercise also enhanced accuracy ($t_{17} = -2.59, P = 0.019, d = 0.61$) during the video game task, with fewer mistakes to eliminate targets in one single attack after exercise (mean ± SEM = 1.39 ± 0.39) than after rest (mean ± SEM = 2.44 ± 0.51) (Fig. 3).

The results of the correlational analysis exploring associations between measures of video game performance with psychosocial outcomes, cognition, LoL rank, cardiorespiratory fitness, and physical activity patterns are shown in Table 3. The short-term positive and negative affective response to exercise assessed with the PANAS did not correlate with the number of targets eliminated or mistakes made during the video game task. Similarly, the level of enjoyment assessed with the Physical Activity Enjoyment Scale did not correlate with any of these two measures of video game performance. Cognition status, current rank in LoL, cardiorespiratory fitness ($\dot{V}O_2$ peak), physical activity, and sitting time were not significantly associated with game performance. Only the general cognitive status of the participants, provided by the NIH toolbox composite score, was positively correlated ($r = 0.62, P = 0.006$) with cardiorespiratory fitness ($\dot{V}O_2$ peak) (Table 3).

**DISCUSSION**

We investigated the effects of a single bout of intense cardiovascular exercise on the performance of LoL. Fifteen minutes of HIIT, performed 20 min before playing this popular video game, enhanced game performance. Exercise improved the capacity to eliminate targets by 9% and increased the accuracy of the attacks by 75%. Consistent with previous reports (38), we also found that exercise increased immediate positive affect by 17% but had negligible effects on negative affect measured with the PANAS. Neither the immediate changes in affect after exercise nor the general level of enjoyment derived from cardiovascular activities were associated with exercise-induced improvements in video game performance. Similarly, cognitive status, LoL rank, cardiorespiratory fitness, and physical activity patterns did not appear to influence the capacity of players to improve video game performance after exercise.

Physical activity and video gaming are usually regarded as two noncomplementary and time-competing activities (39). The negative association between these two activities appears to be especially strong in players of games like LoL (9), although the reasons for such a strong negative association in this video game genre specifically are still to be determined. This is, to our knowledge, the first study exploring interactions between exercise and video game performance. Our results challenge the preponderant view that the relationship between physical activity and video gaming must be antagonistic by nature (27). By contrast, our study suggests that the introduction of short bouts of intense cardiovascular exercise before video game playing could enhance game performance and, at the same time, promote improvements in the physical and cognitive well-being of this rapidly growing population at risk of cardiometabolic (40) and psychosocial (22) problems.

We also analyzed potential psychosocial factors to explore if they had any influence on the effects of exercise on video game performance. The aim of this analysis was simply to determine whether gamers who do not enjoy or who are not particularly attracted to this type of exercise could still benefit from its positive effects on video gaming (41). The null associations between affect and enjoyment with improvements in game performance suggest that these two aspects were not major factors influencing the effects of exercise on video game skill. However, these results should be interpreted with caution because none of the participants displayed marked negative affective responses after exercise nor reported low levels of enjoyment with cardiovascular exercise. Hence, we cannot confirm

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**FIGURE 2**—Total number of target enemies eliminated during the LoL task. Note how the total number of target enemies eliminated was greater after exercise ($t_{17} = 2.41, P = 0.027, d = 0.57$) than after the period of rest. Error bars represent SEM. $^*P<0.05$.

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**TABLE 2.** Physiological and affective responses after the rest and exercise conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>HRpeak (bpm)</th>
<th>RPE</th>
<th>PANAS positive effect</th>
<th>PANAS negative effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>90.58 ± 2.66</td>
<td>6.22 ± 0.17</td>
<td>26.22 ± 1.83</td>
<td>13.66 ± 1.32</td>
</tr>
<tr>
<td>Exercise</td>
<td>188.22 ± 2.86*</td>
<td>15.17 ± 0.34*</td>
<td>30.67 ± 1.46*</td>
<td>13.55 ± 0.93</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SEM. $^*P<0.05$. 

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that gamers with a strong aversion or negative affective responses to exercise (42) would show the same exercise-induced enhancements in video game performance that we observed in this study.

Although cardiorespiratory fitness (VO_{peak}) was not associated with video game performance, it correlated with general cognitive status (r = 0.617). Associations between cardiorespiratory fitness and cognitive status have been reported previously, although the strength of these associations varies substantially depending on individual factors (e.g., sex, age) as well as the cognitive domain assessed (17). Because playing video games like LoL requires intense cognitive processing (5), we expected an association between VO_{peak} and game performance. This association would have supported the exciting hypothesis that improving cardiorespiratory fitness has a positive effect on video gaming, providing a strong argument to convince sedentary video gamers to change their physical activity habits (9, 10), using cardiovascular exercise to improve their video game performance and, in turn, their cardiorespiratory fitness. In any event, the null association between VO_{peak} and improvements in game performance after exercise has a positive connotation. Our results suggest that, regardless of their fitness level, most players may still benefit from the effects of a single session of exercise to improve their video game skills.

Because this study was not designed to identify the mechanisms underlying the effects of cardiovascular exercise on video game performance, any potential mechanistic explanation presented here remains theoretical. However, there is strong evidence that a bout of cardiovascular exercise performed immediately before executive-control cognitive tasks can facilitate their performance (25). The mechanisms behind such facilitation include transient increases in processing speed, attention, working memory, and cognitive flexibility (i.e., shifting) (43). Our customized LoL task targeted core components of executive function commonly involved in action video gaming such as inhibition, updating of working memory, and shifting (19). Indeed, to eliminate targets timely and precisely, participants had to inhibit the launch of unsuccessful attacks, update continuously the position and life status of opponents, and switch between different tasks. Given the consistently positive effects that acute cardiovascular exercise has shown to have on executive functioning (25), it is possible that the improvements in game performance observed in this study were due to an exercise-induced facilitation of this aspect of cognition.

More research will be needed to investigate the specific mechanistic underpinnings underlying the effects of exercise on video game performance. Neuroimaging techniques such as electroencephalography and functional magnetic resonance could be used to determine which areas of the brain are specifically activated during the practice of specific video game task (44) and how these brain areas adapt to both the acute and chronic effects of exercise (20) to gain insight into the specific neural correlates subserving the effects of exercise on video game performance. Eye tracking technologies and/or psychophysiological techniques could be used to study whether exercise-induced changes in visual attention and/or arousal could also contribute to the positive effects of exercise on video gaming (45). Finally, future research efforts should be directed at exploring the use of multimodal strategies combining different exercise interventions and video games to study their potential additive effects to improve different aspects of cognition, both in nondisabled individuals and in people with cognitive impairments.

**LIMITATIONS**

This study has two main limitations that need to be acknowledged. First, we used a within-subject design to increase statistical power, but the sample size was relatively small. We could not estimate the required sample power *a priori* because

![FIGURE 3](http://www.acsm-msse.org)

**TABLE 3.** Correlational analysis exploring associations between measures of video game performance with psychosocial outcomes (affect and enjoyment, cognition, cardiorespiratory fitness, and physical activity measures).

<table>
<thead>
<tr>
<th>Targets Eliminated</th>
<th>Accuracy Mistakes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
</tr>
<tr>
<td>Positive effect</td>
<td>r = 0.02</td>
</tr>
<tr>
<td>Negative effect</td>
<td>r = 0.09</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>r = 0.46</td>
</tr>
<tr>
<td>Cognitive score</td>
<td>r = -0.20</td>
</tr>
<tr>
<td>Current rank</td>
<td>r = 0.32</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>r = -0.23</td>
</tr>
<tr>
<td>Physical activity</td>
<td>r = -0.37</td>
</tr>
<tr>
<td>Sitting time</td>
<td>r = 0.24</td>
</tr>
</tbody>
</table>

Data are presented as correlation coefficients (r) and probability (p) values.
of the lack of previous data. However, a larger sample size would surely allow for a more reliable exploration of the many factors potentially mediating the effect of acute exercise on video game performance using mediation analysis. Second, the assessors who scored the video game task were not blinded to the allocation of participants to the experimental conditions. It should be noted, however, that the total number of targets eliminated was provided by the game itself and that the consistency among assessors in scoring accuracy errors independently was excellent. Therefore, the possibility of unconscious assessor bias in this study is unlikely.

CONCLUSIONS

This study provides the first evidence that exercise and video gaming are not mutually exclusive activities and that exercise can, in fact, enhance video game performance. The study suggests that the effects of exercise on video gaming are not dependent on the individual psychosocial response to exercise in terms of affect or enjoyment nor the level of fitness of the video gamer. More studies will be needed to establish whether these enhancing effects are generalizable to other video games, whether repeated bouts have summative effects, and to identify potential underlying mechanisms.

During this study, MR received funding from the Fonds de La Recherche de Québec Santé (FRQS) Salary Award Junior I. The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. These results do not constitute endorsement by the American College of Sports Medicine.

REFERENCES