Chronic Effect of Static Stretching on Strength Performance and Basal Serum IGF-1 Levels

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ABSTRACT

Borges Bastos, CL, Miranda, H, Vale, RGS, Portal, MDN, Gomes, TM, Novaes, JS, and Winchester, JB. Chronic effect of static stretching on strength performance and basal serum IGF-1 levels. J Strength Cond Res 27(9): 2465–2472, 2013—Improving the process of how physical performance is enhanced is one of the main topics evaluated by physiologists. This process often involves athletes and nonathletic populations. The purpose of this study was to assess the chronic response to 10 weeks of static stretching exercises carried out before and during a strength training program for 8 exercises on an 8 repetition maximum (8RM) test performance, and basal serum insulinlike growth factor (IGF-1) levels. Thirty recreationally trained volunteers were randomly assigned to 1 of 3 training groups: (a) SBST (performed a warm-up with a static stretching protocol before each strength training session); (b) SDST (before each training set, a static stretching exercise was performed); and (c) OST (entire session was performed without any type of stretching exercise). Strength and IGF-1 levels were collected at the beginning (pretest) and end (posttest) of the entire experimental procedure. All the exercises showed a significant increase in muscle strength for the OST group. However, the results revealed a significant increase in the muscle strength for only a few exercises in the SBST (LP, LE) and SDST (LP) experimental conditions. Significant statistical differences were found between SBST and SDST for all the exercises in the OST experimental condition. Furthermore, the IGF-1 expression showed no significant differences in the intragroup analysis. However, the OST group showed higher values ($p < 0.05$) in the posttest when compared with those of the other groups (increased significantly only in the OST experimental condition). It has been concluded that, although all the groups showed an increase in muscular strength, the strength training performed without any type of stretching exercise, regardless of whether the stretching is performed before or during the lifting session, can more effectively increase muscle strength and basal serum IGF-1 levels. It was concluded that strength training, with or without the use of stretching exercises, increased muscular strength in the studied groups, and can induce an increase in IGF-1 levels.

KEY WORDS: warm-up, resistance exercise, hormone, strength, stretching, flexibility

INTRODUCTION

Stretching is commonly performed in sports because of its effectiveness in the maintenance and improvement of joint range of motion. Strength and conditioning professionals, coaches, athletic trainers, and physical therapists often recommend stretching before competition or a strenuous activity because of the belief it can improve athletic performance and reduce the risk of musculoskeletal injuries (41).

Recent studies have suggested a negative influence of stretching on the performance of acute dynamic strength (2,13,31), isometric (8,32), and isokinetic (7,24). In contrast to the acute effects, performing stretching exercises over a long period (chronic effect) seems to cause significant increases in strength performance. For example, Kokkonen et al. (18) observed increases of up to 31% in the 1RM test performance after an 8-week static stretching program comparing strength training in isolation and combined with static stretching exercises for the musculature of the hip, thigh, and plantar flexors. Ress et al. (33) and LaRoche et al. (20) observed increases in isometric test performance for plantar flexors and peak torque, respectively, when the...
tests were conducted after training with only stretching exercises for 4 weeks.

Ress et al. (33) suggest that increases in strength may occur in increments in the myotendinous unit as a response to high mechanical stress on the tendons and muscles. This mechanical stress contributes to changes in the collagen structure and to the protein synthesis response needed for hypertrophic adaptation to occur. In animal studies, Coutinho et al. (5) showed that passive stretching stimulates protein synthesis and the addition of sarcomeres along the muscle fiber that corresponds to the release of growth factors such as insulin-like growth factor 1 (IGF-1) along with the increased expression of mRNA for muscle proteins, a result that was not observed in the Gomes et al. (12) study.

The IGF-1 is an important anabolic agent in the body and is integral for protein synthesis throughout life (30). This hormone is closely related to muscle mass, conservation of the musculoskeletal system, metabolic rate, and muscle strength (4,10,14,23). Wilborn et al. (39) showed that skeletal muscle fibers can develop with increasing IGF-1 intake in response to resistance training. However, body composition, nutritional status, energy balance, and type of exercise can influence both the manner and the magnitude of response (22,34).

It is usual to see lifters performing strength training with interset stretching in an effort to improve muscular recovery both in sport- or recreational-related facilities (9). Additionally, it is suggested that interset stretching influences the time under tension and the associated neuromuscular, metabolic, and hormonal responses, with a possible contribution to increase the hypertrophic effect (29). On reviewing the pertinent literature, we found no studies that examined the chronic effect of strength and flexibility training on hormonal responses, particularly on IGF-1 secretion in humans. Therefore, the purpose of this study was to assess the chronic effects of static stretching exercise carried out before and during a strength training program on 8-repetition maximum (8RM) performance and serum IGF-1 levels only at the beginning (pretest) and end (posttest) of the entire experimental procedure to compare the chronic effects during 10 weeks of the use of static stretching exercises before and during a strength training program on the 8RM test and basal serum IGF-1 levels. The exercises selected for the 8RM test were as follows: bench press (BP), lat pull-down (LP), leg extension (LE), and leg curl (LC). The training was carried out in Brazil during March to May.

Subjects
Thirty participants who were recreationally trained participated in the study. The descriptive characteristics of the volunteers are presented in Table 1. For the purposes of this study, recreationally trained was defined as having at least 1 year of experience with the strength and flexibility exercises proposed in the study. Before initiation of the research project, the subjects performed weight training with a mean frequency of 4 sessions per week for approximately 1 hour per session and, predominantly, 1- to 2-minute rest periods between sets and exercises. It was recommended to the subjects to follow a diet throughout the study period, balanced on protein (15%), fat (<30%), and carbohydrates (60–70%). The amount of protein daily diet was estimated from 1.2 to 1.4 g kg\(^{-1}\) of body weight per day for each individual. All the subjects answered the Physical Activity Readiness Questionnaire (35), and each subject signed a witnessed informed consent statement describing risks, benefits, and responsibilities of participation, and the option to withdraw at any time without prejudice in the study according to the Declaration of Helsinki. Moreover, the subjects did not allow their sleeping, eating, and drinking habits to change throughout study participation. The study was approved by the Human Research Ethics Committee of Castelo Branco University (Rio de Janeiro—Brazil).

The 8RM Test
The subjects underwent 4 familiarization sessions with the 8RM test to observe the moment of concentric failure in the exercises used. Several protocols for predicting training loads and maximum strength have reported in the literature—1RM (14,40); 8RM (27,28); 10RM (36). In our study, we used the 8RM (27,28) to be a number similar to that used in training centers in which our participants regularly exercised before the onset of the study.

The 8RM tests (27,28) were then given to the individuals on 4 different days with a minimum interval of 72 hours; the BP and LE exercises were used on the first and third days, and the LP and LC exercises on the second and fourth days. At the start of the sessions, the subjects warmed up with 10 repetitions using 60% of the maximum weight. After 1 minute of rest, 5 repetitions using 80% of maximum weight were performed. During the 8RM tests, each subject performed a maximum of 5 attempts at each exercise with intervals of 3–5 minutes between them. After obtaining the 8RM load
on the first exercise, an interval of not < 5 minutes was given before proceeding to the next exercise. The 8RM load was considered to be the highest weight obtained on both days (test and retest) with a difference of < 5%. In the case of a larger difference, the subjects were asked to perform a new test, so that the difference could be recalculated. Exercises that could interfere with the results obtained were not permitted between test sessions. No pause was allowed between the concentric and eccentric phases of the repetition or between repetitions.

To reduce the margin of error in the 8RM test, the following strategies were adopted: (a) standardized instructions and familiarization before the test, so that all those evaluated were aware of the entire data collection routine; (b) those evaluated were instructed on exercise performance techniques; (c) the evaluator was mindful of the position adopted by the practitioner at the time of measurement, because small variations in the positioning of the joints involved in the movement could trigger other muscles, leading to misinterpretations of the scores obtained; (d) verbal stimuli were used to maintain a high level of stimulation; (e) the additional weights used in the study were previously calibrated on a precision scale (Filiżola, São Paulo, Brazil); and (f) for the repetition to be validated, a complete range of motion needed to be performed.

After 10 weeks of training, the 8RM posttest was conducted under the same conditions and criteria. Reliability for the 8RM test was shown with the use of this protocol. Nine subjects of the sample, selected randomly (3 from each training group), were tested on occasions separated by 72 hours. The results obtained show an intraclass coefficient of 0.92, 0.90, 0.93, and 0.92 to BP, LP, LE, and LC, respectively. A paired-samples t-test was performed and did not demonstrate any significant difference (p < 0.05) between 8RM tests on separate testing occasions.

IGF-1 Assessment
Basal serum IGF-1 levels were analyzed in a clinical analysis laboratory using the Immulite—DPC Med Lab chemiluminescence method. Vacuum blood collection (closed system) was performed using the following materials: cotton, 70% alcohol, disposable needle (0.80 x 25—sterile), disposable syringe (5 or 10 ml), "garrotte" or "tourniquet," and sterile tube without anticoagulant, with a separating gel. The collected blood was immediately centrifuged at 3,500 rpm for 10 minutes for at least 1 ml of serum. The serum was kept refrigerated until all the samples were collected. The serum of each sample was placed on a rack with proper identification. The analysis was done by the chemiluminescence method during a period of 3 minutes. The results were sent to a central computer by interfacing. All the samples were tested in duplicate. The examinations were always performed in the morning between 6:00 and 7:00 AM after a 12-hour fast.

Training Program
The strength training program lasted 10 weeks and consisted of 3 weekly sessions with 48-hour intervals, for a total of 30 sessions. The program was composed of 8 exercises performed in 4 sets of between 8 and 10RM, with an interval of 90 seconds between both sets and exercises. The exception in terms of loading was for trunk flexion (abdominal) and trunk extension (low back) exercises, in which 4 sets of 15–20RM were performed. The training weights were adjusted based on participants' 8RM and were readjusted when the volunteers were able to perform 10RM in all sets of each exercise. Loading was increased until the point at which the lower limit of repetitions (8RM) was reached.

The exercises were chosen to generate balanced muscular development. We used the agonist and antagonist training method in the following exercises performed in the 3 experimental groups: BP; LP; LE; LC; triceps extension; biceps curl; trunk flexion and trunk extension. All exercises were performed on Life Fitness weight stack equipment (Franklin Park, IL, USA).

Training protocols were differentiated as between groups as follows:
In the SBST, the subjects performed a warm-up with 4 exercises of static stretching at the beginning of each strength training session, with the muscle held in the stretched position for 30 seconds.

<table>
<thead>
<tr>
<th>TABLE 1. Subject characteristics.*</th>
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<tr>
<td>Group</td>
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<tr>
<td>SBST</td>
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*BMI = body mass index, SW = Shapiro-Wilk.
In the SDST, the subjects performed a specific warm-up consisting of 1 set of 15 repetitions with 50% of the weight of the first exercise of the sequence. Next, a sequence of strength training was carried out as described above; however, stretching exercises for a specific muscle were performed immediately before completing the lift for that same muscle. All the stretches were performed statically and were held in the stretched position for 30 seconds.

In the OST, the subjects performed a specific warm-up consisting of 1 set of 15 repetitions with 50% of the weight of the first exercise of the sequence. Next, a sequence of strength training was performed as described above without any type of stretching exercise.

**Stretching Protocol**

To ensure the same total volume of stretching for all the groups (SBST and SDST) only 1 set for each stretching exercise were used, where the movement was held for 30 seconds at a point of slight discomfort (1,40).

The stretching exercises were performed according to the resistance exercises presented, with stretching performed for the horizontal flexors and extensors of the shoulder, knee and elbow extensors and flexors, and hip extensors (Figure 1).

**Statistical Analyses**

The statistical analysis was initially done by the Shapiro-Wilk and Levene tests to establish normal distribution and homogeneity of variance among the 3 experimental groups. Repeated measures analysis of variance (ANOVA) was used to examine the effects of the experimental conditions on the dependent variables (load—kilograms and IGF-1 vs. groups), followed by post hoc test of the least significant difference to identify possible differences. An alpha level of $p \leq 0.05$ was considered statistically significant for all comparisons. PASW Statistics 18.0 (SPSS Inc., EUA) software was used for all statistical analyses.

**RESULTS**

In the OST group, all the exercises showed an increase ($p < 0.05$) in the muscular strength (Table 2). The SBST group showed an improvement in the LP and LE ($p < 0.05$), and the SDST group showed improvement in the LP only ($p < 0.05$; Table 2). Significant statistical differences were found between SBST and SDST for all the exercises as compared with that for the OST experimental condition (Table 2). The experiment observed power in the variable muscle strength was 89%.

**Table 2.** Comparative analysis of muscle strength in the 8RM test for the BP, LP, LE, and LC exercises.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Groups</th>
<th>Pretest (mean ± SD)</th>
<th>Posttest (mean ± SD)</th>
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<tbody>
<tr>
<td>BP (kg)</td>
<td>SBST</td>
<td>75.80 ± 7.27</td>
<td>81.40 ± 18.14</td>
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<td>SDST</td>
<td>85.60 ± 21.76</td>
<td>89.50 ± 20.34</td>
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<tr>
<td></td>
<td>OST</td>
<td>89.20 ± 16.20</td>
<td>106.20 ± 18.70†‡</td>
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<td></td>
<td>SDST</td>
<td>52.50 ± 9.79</td>
<td>63.4 ± 8.53†</td>
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<tr>
<td></td>
<td>SDST</td>
<td>55.50 ± 7.25</td>
<td>63.5 ± 7.58†</td>
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<td></td>
<td>OST</td>
<td>58.00 ± 5.37</td>
<td>77.6 ± 11.82†</td>
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<tr>
<td>LP (kg)</td>
<td>SBST</td>
<td>35.50 ± 7.62</td>
<td>43.30 ± 8.30†</td>
</tr>
<tr>
<td></td>
<td>SDST</td>
<td>33.00 ± 6.32</td>
<td>37.60 ± 5.58</td>
</tr>
<tr>
<td></td>
<td>OST</td>
<td>39.50 ± 7.62</td>
<td>52.70 ± 13.31†‡</td>
</tr>
<tr>
<td>LE (kg)</td>
<td>SBST</td>
<td>26.00 ± 4.59</td>
<td>30.60 ± 4.77</td>
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<tr>
<td></td>
<td>SDST</td>
<td>25.00 ± 4.71</td>
<td>29.00 ± 5.16</td>
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<tr>
<td></td>
<td>OST</td>
<td>30.50 ± 4.97</td>
<td>38.60 ± 11.04†‡</td>
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</tbody>
</table>

*SBST = group that stretched before strength training; SDST = group that stretched during the strength exercises; OST = group that only performed strength training, without stretching.

†Significant difference ($p < 0.05$) compared with pretest.

‡Significant difference ($p < 0.05$) compared with SBST-post and SDST-post.
Comparative analysis of IGF-1 in the sequences. Significant differences (p < 0.05) compared with SBST-post and SDST-post. SBST = group that stretched before strength training; SDST = group that stretched during the strength exercises; OST = group that only performed resistance training, without stretching.

**Figure 2.** Comparative analysis of IGF-1 in the sequences. Significant difference (p < 0.05) compared with SBST-post and SDST-post. SBST = group that stretched before strength training; SDST = group that stretched during the strength exercises; OST = group that only performed resistance training, without stretching.

increased (p < 0.05) only in the OST experimental condition (Figure 2) when compared with other posttest experimental groups showing an experiment observed power of 68% in the variable IGF-1.

**DISCUSSION**

The key finding from this study was that although all 3 experimental groups (SBST, SDST, OST) improved their strength as a result of the 10-week training regimen, the group that did resistance training without stretching experienced significantly greater gains in strength as compared with the other 2 groups. All the exercises showed a significant increase in the muscle strength for the OST group. However, the results revealed a significant increase in the muscle strength for only a few exercises in the SBST (LP, LE) and SDST (LP) experimental conditions. This indicates that stretching compromised increments in strength achieved by resistance training. Moreover, the data appear to show that neither form (or presentation) of stretching exercises (i.e., all of it done before beginning resistance exercise, or interspersing stretching activities between sets of lifting) is superior to the other with respect to amplifying strength gains derived from lifting. In fact, it appears that both methods impaired strength enhancement similarly. This is consistent with other work in this area (2,13,31) and indicates that stretching compromised potential improvements in strength achieved by resistance training. These findings have potentially important implications for strength and conditioning professionals and other exercise professionals who may commonly use stretching exercises as an integral part of a warm-up routine or, during the training session itself.

After an intervention consisting of 15 days of static stretching proprioceptive neuromuscular facilitation (PNF) for the hamstring muscles, Worrel et al. (42) found significant increases in the maximum voluntary torque in an isokinetic test. Eccentric torque increased 8.5 and 13.5% at 60 and 120°·s⁻¹, respectively, and concentric torque increased 11.2% when analyzed at 120°·s⁻¹. In a similar study, Kokkonen et al. (17) observed significant increases in vertical jump performance (6.7%), 20-m sprint (1.3%), 1RM for knee extensors and flexors (32.4% and 15.3%), and local muscular endurance of the knee extensors and flexors (28.5 and 30.4%) after 15 different stretching exercises for the lower limb muscles were performed over 10 weeks. The results of previous studies show that stretching exercises can increase muscle strength independently of specific resistance training. In this study, the performance of stretching exercises along with specific strength exercises also increased muscle strength. It is worth noting the disparate methodological differences between studies as an important influencing factor in the adverse outcomes among them. Worrel et al. (42) performed 4 stretching sets for each method used (static and PNF), whereas this study only carried out 1 stretching set for each exercise. Kokkonen et al. (17) performed a total of 15 stretching exercises, whereas this study used 4 exercises. The differences between the amount of stretching stimuli may have influenced the study responses, which could have improved or minimized the positive effects that stretching exercises can have on strength performance. However, contrary to what we expected in our hypothesis, more significant increases could be observed when volunteers only performed resistance exercises. Mohamad et al. (29) reported that the stretch between sets of TF could increase muscle hypertrophy and suggest the possibility of also increase muscle strength in relation to strength training alone. But it is important to emphasize that our study did not assess muscle hypertrophy, which should be observed in future studies. It is also important to note that our inclusion of stretching, either before or during the actual resistance training session, may have reduced the intensity at which our participants were able to train. There are multiple studies suggesting acute strength impairments after the performance of static stretching and this phenomenon could easily have affected not only the chronic adaptations we observed but also within session loading. Quite obviously, any decrease in acute training loads could have contributed to the differing amounts of strength gains between groups.

Kokkonen et al. (18) conducted research to verify the differences in lower limb strength gains in physically active individuals, comparing strength training in isolation and combined with static stretching exercises for the hip and thigh muscles and plantar flexors. They found significant strength increases in the lower limbs for both groups. However, the greatest differences were observed in the group that performed strength training in combination with stretching exercises (16, 27, and 31% in the 1RM test for knee flexion, knee extension, and leg press exercises, respectively). The data from our study showed an increase of 21.97% in the knee extension exercise in the SBST group, corroborating with Kokkonen et al. (18). However, in this study the largest increases in strength could be observed in OST group, where
increases of 26.56, 33.42, and 33.79% in the 1RM test for the LC, LE, and leg press exercises was verified. The differences in strength gains may have occurred because the amount of training has varied among studies. Although Kokkonen et al. (18) performed 15 different stretching exercises totaling 30 minutes in each session, this study carried out just a single stretching exercise for each muscle in a single set. The low amount of stretching in this study may have minimized increases in muscle strength for groups that made stretching exercises, because it was observed that the OST group obtained higher results than did the SBST and SDST groups. Based on previous studies, there seems to be a greater likelihood of strength increases from performing stretching exercises when a high volume of training is carried out. The order at which the stretching was introduced relative to the resistance exercise was also different in the Kokkonen study as compared with our current investigation. It may be that there is an order effect where stretching included after a lifting session is complete can enhance performance but stretching performed before or during, impairs gains. More data are needed to state these claims with any certainty, but the current body of literature seems to warrant such speculation at this point.

In animal studies, the hypothesis of increased strength after flexibility training seems to be based on increases in cross-sectional areas and also in myoblast proliferation (5,6,37). Staub et al. (37) observed increases of 13% in muscle mass and 30% in the cross-sectional area of the soleus muscle in rats after 4 weeks of static stretching. Coutinho et al. (5) observed increases of 16% in the cross-sectional area of the soleus muscle in rats after stretching was performed 3 times a week for 3 weeks. Ress et al. (33) suggest that strength increases may occur as a result of high mechanical stresses on the tendons and muscles. This mechanical stress contributes to changes in the collagen structure and to the hypertrophy process. If tension, leading to mechanical stress, is an important stimulus for both structure and hypertrophic response, it is not unreasonable to suspect that placing the muscle on stretch could lead to some of those types of changes when done in the proper fashion.

This study showed significant increases in the IGF-1 levels in the OST group when compared with that of other posttest study groups, which performed strength training without the use of stretching exercises for 10 weeks. These findings are corroborated by Borst et al. (3), who observed elevations of this hormone in both groups that performed strength training in single and multiple sets for 25 weeks. Marx et al. (26) compared low and high training volume circuits with multiple sets over 6 months of intervention and observed higher magnitudes of increased IGF-1 in the group that trained with multiple sets. The total duration of the training programs may have influenced these findings (19), but this study reached changes in IGF-1 in less training time.

High-intensity training appears to be another important factor in generating IGF-1 increases. West et al. (38) found increases in IGF-1 after 15 weeks of high-intensity strength training (90% 10RM), performing a serum collection analysis 15 minutes after the last training session. This confirms the results found in the OST group in this study, which engaged in high-intensity training. Perhaps preactivity stretching or within session stretching reduced volitional strength to the point that sufficient intensity to achieve significant IGF-1 release could not be achieved in either the SBST or the SDST group. This suggests that the intensity of exercise may be greater without the presence of stretching exercises, requiring greater effort on the part of the participant (30). Thus, the significant increase noted in IGF-1 in the OST group posttest can perhaps be justified by the greater intensity of effort made in training sessions. Mechanistically, one may suggest that the OST group had a higher stimulation in the activity of the sympathetic division of the autonomic nervous system, which led to increased secretion of growth hormone (GH) and circulating IGF-1 (10).

However, the findings of Izquierdo et al. (16) contrast with the results of the OST group in this study, because they found an IGF-1 reduction with 16 weeks of strength training (60–90% 1RM), using different warm-ups and relaxation with stretching exercises at the end of the sessions in the group that exercised to muscular fatigue. The other group studied, which did not work to muscular fatigue, showed no significant changes, as was observed in the SBST and SDST groups in this investigation. However, we again see a group that did use stretching along with resistance exercise and observed significant strength gains, but performed at the end, rather than as a warm-up or within session.

The IGF-1 responses and the different strength training strategies used in this study are corroborated by Liu et al. (21), who analyzed muscle strength performance using the 1RM test and IGF-1 levels in 24 subjects divided into 2 groups (A and B) for 6 weeks of strength training. Group A performed strength training with maximum contraction exercises and group B used exercises combined with ballistic movements and stretching in short stimulus cycles. Analysis of the brachial triceps biopsy was conducted 3 days before and 7 days after training. The results showed that both groups significantly increased muscle strength, but only group A, which just performed strength training, obtained a significant increase in IGF-1 (335%). The authors suggested that these results may be because of increased activation of satellite cells involved in the process of muscular adaptation to the training and the greatest changes in the myosin heavy chain provided by the strategy used in group A. These findings could explain what occurred in the OST group in this study because the results were similar, although a muscle biopsy has not been done for confirmation, but IGF-1, whose expression is increased by strength training, stimulates the proliferation, differentiation, and fusion of satellite cells in growing myotubes (11).

The mechanical growth factor (MGF) is an isoform of IGF-1 that has its expression increased after a muscle exercise.
overload, preceding the activation of satellite cells, whereas systemic IGF-1 has its expression increased more slowly (15). In turn, insulin, by promoting glucose uptake in skeletal muscle and been essential to the functioning of the muscle cell, appears to be responsible for the proliferation and differentiation of satellite cells through the IGF-1 receptors (25). This does, however, bring up an important limitation in our current work. Because IGF-1 is only one of many circulating androgens, and also because it does not represent androgens released in local fashion such as MGF, it is important not to over generalize on the role that IGF-1 may or may not have played in the improvements or lack thereof observed in this investigation. Our article has limitations regarding the collection of blood of IGF-1 levels. We know that these blood levels can be altered by several factors involved, many of which could not be controlled by us. The type of diet, lifestyle, stress, sleep, alcohol intake, among others, may affect these levels. For a better understanding of the differences of these levels in athletes on training, it would be interesting to collect at various times throughout the training and to monitor binding proteins that play a big role, for example, IGFBP-3, GH, satellite cells. Thus, it is difficult to say if it was the strength training or the stretching training that increased the final value of IGF-1.

Rubin et al. (34) demonstrated that plasma IGF-1 concentrations are higher in trained than in untrained individuals. However, other factors that were not investigated in this study may interfere with IGF-1 secretion, such as GH levels. IGF-1 concentrations are highly regulated by the GH secretion (10) but, being pulsatile, the highest secretion level occurs at night. Thus, this hormone was not examined in this study.

It has been concluded that strength training performed at a loading intensity of approximately 8–10RM with a specific warm-up consisting of a set of 15 repetitions with 50% of the weight and without any type of stretching exercise can increase the muscle strength. This study also suggests that the training used in the OST group may have been more intense than the applied training in the other groups providing higher values of IGF-1 in posttest. Therefore, the results of this study are highly applicable to actual training scenarios. However, additional research would be needed for further evaluation of these variables, particularly with regard to IGF-1 and other associated hormones as suggested before. It would be interesting to perform a similar study with more additional protocols to assess the mechanisms behind any observed performance change such as electromyographic analysis, muscle thickness assessment, or even taking muscle biopsies for protein analysis. Nevertheless, we feel that our current investigation does add important data to the current body of literature and has legitimate practical implications and potentially mechanistic ones as well.

Practical Applications

The results of this study are very relevant in that they can be used by the strength and conditioning professional to improve the manner in which sessions of exercise are implemented. Strength training programs that are preceded by flexibility training or where stretching is executed between the sets or lifts are likely to make smaller gains in strength as compared with performance of strength training alone. Strength and conditioning professionals who desire to include static stretching into their sessions should consider implementing it at the end of the session and use a dynamic or specific warm-up before training. Practitioners wishing to include some form of isometric mobility exercise should avoid static stretching and may wish to consider a more dynamic form of exercise.

References

Strength Performance, Static Stretching, and IGF-1 Levels


