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Revista de Cercetare si Interventie Sociala

ISSN: 1583-3410 (print), ISSN: 1584-5397 (electronic)

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Revista de cercetare și intervenție socială, 2019, vol. 66, pp. 328-341

https://doi.org/10.33788/rcis.66.19

Published by:
Expert Projects Publishing House

expert projects
publishing

On behalf of:
„Alexandru Ioan Cuza" University,
Department of Sociology and Social Work
and
HoltIS Association

REVISTA DE CERCETARE SI INTERVENTIE SOCIALA
is indexed by Clarivate Analytics (Web of Science) -
Social Sciences Citation Index
(Sociology and Social Work Domains)

Effects of Different Stretching Strategies on Soccer Players' Power, Speed, and Muscle Strength Performance

Ronghai SU[1], Chunoh WEI[2], Maochou HSU[3]

Abstract

Effects of 4 different stretching strategies on power, speed, and muscle strength performance are discussed. 60 soccer players (aged 20.06±1.25, height 177.37±2.62cm, weight 73.40±6.01kg), as the research subject, are randomly divided into static group, static+dynamic group, dynamic group, dynamic+static group, and control group. With balance-order repeat-measure experimental design, counter movement jump, 50m sprint, and isokinetic strength are tested before, during, and after each experiment, with the experiment interval 72hr. The results reveal that 1) static stretching shows negative effects on power performance, dynamic stretching presents gain effects on power performance, and static+dynamic stretching is the best stretching strategy for power training, 2) static stretching appears significant effects on speed performance, dynamic stretching could remarkably enhance speed performance, and dynamic stretching is the best stretching strategy for speed training, and 3) static stretching shows notably effects on muscle strength performance, dynamic stretching presents significantly positive effects on muscle strength, and dynamic+static stretching is the best stretching strategy for muscle strength training.

Keywords: stretching, power, dash speed, muscle strength, exercise performance, static stretching, dynamic stretching.

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Introduction

Static stretching refers to slowly extending the stretched parts to certain fixed posture and then stretch. It shows the characteristic of expanding joints to certain proper angles and maintaining the static state for a period time. In the field of exercise training, static stretching is the broadly applied stretching in warm-up. Although static stretching could relax muscles and enhance tendons and joint motion (Small, K *et al.*, 2008), a lot of research found out the acute negative effects of static stretching on exercise performance and up to 24hr negative effects on power and speed (Haddad *et al.*, 2014) , the decrease in 1mile endurance run performance and the extension of time for ground contact during running (Lowery *et al.*, 2014), the reduction of noncontractile resistance of muscles and tendons (Nakamura *et al.*, 2013), as well as the significant reduction of muscle strength performance (Serra *et al.*, 2013). Beckett *et al.* (2009) discovered that static stretching showed less effects on directional motion, but would remarkably affect straight dash. Kistler *et al.* (2010) found out the notably dropping speed in 20~40m, after the static stretching, that the 100 m performance was worse than athletes without static stretching. Simic, Sarabon, & Markovic et al. (2013) studied the effect of static stretching on muscle strength performance with Meta-analysis and revealed that static stretching would result in muscle strength performance decreasing 5.4%, power output decreasing 1.9%, and power performance decreasing 2.0%. Moreover, the longer static stretching time would cause the larger negative effects, but less negative effect appeared on static stretching within 45s. Some researchers therefore suggested replacing static stretching with dynamic stretching for some activities.

Dynamic stretching refers to stretching with rhythmic and faster speed, increasing range, and repeat motions. Previous research affirmed the positive effect of dynamic stretching on exercise performance. In terms of speed, Fletcher and Jones (2004) studied 97 football players and discovered that dynamic stretching could enhance the exercise performance on 20m sprint. Regarding power, Curry *et al.* (2009) revealed that dynamic stretching could better enhance the exercise performance on vertical jump than static stretching. In regard to agility, McMillian *et al.* (2006) discovered that 30 students in The United States Military Academy, after dynamic stretching, outperformed the static stretching group and the control group on the successive agility test (T-run). Other relevant research (Chattong *et al.*, 2010) presented the similar effect, and dynamic stretching could be applied to team sports (Gabbett, 2008). From above results, dynamic stretching could actually enhance exercise performance, especially on speed, power, and agility performance. There were also reports on the negative effect of dynamic stretching. Miller (1998) considered that dynamic stretching might result in muscle soreness and sports injury as well as induce stretch reflex and increase muscle tone to cause difficulties in completely stretching tissues. Moreover, few researchers studied the combination of static stretching and dynamic stretching and encouraged the application to training. Research (Gelen *et al.*, 2012) revealed that simple dynamic stretching or static stretching did not appear notable differences on hip flexion and extension, while the combination of the two could effectively enhance hip flexion and extension.

In sum, there is not a final conclusion about the effects of static stretching or dynamic stretching on power, speed, and muscle strength performance; and, research on the combination of static stretching and dynamic stretching was little. It is therefore considered in this study about the effect of static stretching or dynamic stretching on exercise performance; and, based on the mechanism, it is also considered whether the combination of such two stretching strategies could improve exercise performance. For this reason, 4 stretching strategies of static stretching, static stretching+dynamic stretching, dynamic stretching, and dynamic stretching+static stretching are designed, aiming to discuss the acute effects on power, speed, and muscle strength performance.

Methodology

Research subject

60 soccer players, aged 20.06±1.25, height 177.37±2.62cm, and weight 73.40±6.01kg, are selected as the research subjects. The experiment process is explained before the experiment, and the subjects are requested to sign the subject consent before the experiment. During the experiment, the subects, without taking any drugs, smoking, and drinking, would respond to the physical health questionnaire. The experiment process and procedure are practiced according to the theories related to Declaration of Helsinki (2013).

Experimental design

With balance-order repeat-measure experimental design, 60 research subjects are randomly divided into 5 groups of static group, static+dynamic group, dynamic group, dynamic+static group, and control group. Except the control group, the other groups receive 4 strategies of static stretching, static stretching+dynamic stretching, dynamic stretching, and dynamic stretching+static stretching, and each experiment interval is 72hr. A pretest is practiced before static stretching or dynamic stretching, and a middle test is practiced immediately after static stretching or dynamic stretching. The static group and the dynamic group practice the posttest after sitting sill for 230s, while the static+dynamic group and the dynamic+static group practice the posttest after preceding 230s dynamic stretching and static stretching right after the middle test. The test items contain counter movement jump, 50m sprint, and isokinetic strength.

Experiment process

5 groups precede the pretest before warm-ups. The static group receives static stretching of quadriceps and hamstrings with 1) elevated leg curl 30s and 2) sit and reach 30s, with the interval 10s. The middle test is preceded right after the stretching. They then sit still and rest for 230s and precede the posttest. The static+dynamic group receives the middle test right after lower-limb static stretching. After the middle test, dynamic stretching is further practiced, including 1) standing front kick 30s and 2) heel-ups 30s, with the interval 10s. The posttest is preceded after dynamic stretching. Similarly, the dynamic group and the dynamic+static group adopt the same static stretching and dynamic stretching. The control group does not practice any stretching, but simply practice tests with the same order and time as the other 4 groups.

Experiment equipment

Counter movement jump is used for testing power, which is collected the data with a grating system (Fusion Sport, Smart Speed, Australia). Before the test, a subject, with both feet open the same width as the shoulders, stands on a jump mat. The green signal light on of the equipment stands for the start of the test. The subject bends knees 90° and jump upwards by matching the arms swinging up; the body, when being in the air, is kept straight, and the knees are slightly bended to reduce the pressure when landing. The test is preceded twice, and the one with better performance is selected for recording the jump height, with the unit centimeter (*cm*).

Speed is tested with 50m sprint, and a grating system is also used for collecting the data. Before the test, a subject stands behind the infrared sensing system on the start point. When the green light of the grating system is on, the subject precedes 50m sprint. After passing the infrared sensing systems on the start and the destination, the sprint time, with the unit second (*s*), is recorded. Such a design does not need an order for starting to avoid the interference of response time in the dash speed.

Muscle strength is completed with isokinetic strength test. Biodex system 4 PRO (Shirley, New York, America) is utilized for collecting the data. A subject is first familiar with the uniform motion pattern before the test, in order to guarantee the stability of the test result. In the formal test, the subject is fixed on a comfortable vertical seat, adjusts the length of the knee attachment, and aligns the axis of rotation (lateral epicondyle of femur) and the power head axle center. The subject's lower limbs then complete stretching to 0° and slowly flex to a comfortable position slightly above 90°; the concentric contraction is preceded with 30°/*s* angular velocity, with the unit Newton metre (*nm*).

Statistics

All numerical values are presented with mean and standard deviation ($M \pm SD$), and the test results are tested with repeat measures. Repeat measures refers to the comparison of the same sample preceding twice or several times and then testing the difference. LSD is used for the unplanned comparison, and $\alpha=0.05$ is regarded as the significance standard. Since statistical significance can be easily affected by sample size, the effect size is utilized in this study to assist in judging and explaining the statistical significance, where *Cohen's d* 0.20, 0.50, and 0.80 stand for small effect size, medium effect size, and large effect size, respectively.

Result and analysis

Analysis of power test result

Table 1 reveals significant differences in the static group ($F=375.96$, $p<0.001$); the pretest (56.00±10.94*cm*) remarkably outperforms the middle test (49.45±10.14*cm*), and the *Cohen's d* 0.62 shows the medium effect size. The static+dynamic group presents notable differences ($F=862.71$, $p<0.001$); the pretest (58.27±8.34*cm*) remarkably outperforms the middle test (56.18±8.16*cm*), and the *Cohen's d* 0.25 appears the small effect size. The posttest (61.00±8.84*cm*) significantly outperforms the pretest, and the *Cohen's d* 0.32 reveals the small effect size. Similarly, the dynamic group shows notable differences ($F=869.60$, $p<0.001$); the middle test (62.00±7.07*cm*) remarkably outperforms the pretest (58.64±6.22*cm*), and the *Cohen's d* 0.50 presents the medium effect size. The posttest (61.36±7.75*cm*) significantly outperforms the pretest, and the *Cohen's d* 0.39 shows the small effect size. The dynamic＋static group reveals remarkably differences ($F=557.05$，$p<0.001$). The posttest (59.55±7.87*cm*) notably outperforms the pretest (57.09±9.04*cm*), and the *Cohen's d* 0.29 reveals the small effect size. What is more, the posteriori test of the control group does not appear significant differences.

Table 1: Vertical jump-power test result *(cm)*

	M±SD			F	p
	pretest	middle test	posttest		
static group	56.00±10.94	49.45±10.14Δ	55.00±8.71	375.96	0.00
static＋dynamic group	58.27±8.34	56.18±8.16Δ	61.00±8.84*	862.71	0.00
dynamic group	58.64±6.22	62.00±7.07#	61.36±7.75*	869.60	0.00
dynamic＋static group	57.09±9.04	61.36±8.85#	59.55±7.87*	557.05	0.00
control group	50.67±9.57	50.35±10.01	51.02±9.44	239.42	0.00

Note: #p<0.05 reveals the middle test remarkably outperforming the pretest; *p<0.05 shows the posttest notably outperforming the pretest; Δp<0.05 presents the pretest significantly outperforming the middle test.

Analysis of speed test result

Table 2 shows remarkable differences in the static group (F=2035.55, p<0.001),while the posteriori test does not appear notable differences, possibly because of distinct sample size, number of groups, statistics, and posteriori pair comparison among groups. The static+dynamic group shows significant differences (F=1457.52, p<0.001). The posttest (6.62±0.59*s*) remarkably outperforms the middle test (6.78±0.60*s*), and the *Cohen's d* 0.27 reveals the small effect size. The dynamic group appears notable differences (F=2467.23, p<0.001), and the middle test (6.60±0.44*s*) significantly outperforms the pretest (6.80±0.49*s*). The *Cohen's d* 0.43 presents the small effect size. The posttest (6.49±0.44*s*) notably outperforms the pretest. The *Cohen's d* 0.67 shows the medium effect size. Similarly, the dynamic＋static group presents significant differences (F=1441.96, p<0.001). The middle test (6.60±0.56*s*) remarkably outperforms the pretest (6.78±0.62*s*), and the *Cohen's d* 0.30 shows the small effect size. The posttest (6.64±0.61*s*) notably outperforms the pretest, and the *Cohen's d* 0.23 reveals the small effect size. Moreover, the posteriori test of the control group does not show significant differences.

Table 2: 50m run-speed test result *(s)*

	M±SD			*F*	*p*
	pretest	middle test	posttest		
static group	7.01±0.48	6.95±0.56	6.85±0.54	2035.55	0.00
static＋dynamic group	6.79±0.57	6.78±0.60	6.62±0.59*	1457.52	0.00
dynamic group	6.80±0.49	6.60±0.44#	6.49±0.44*	2467.23	0.00
dynamic＋static group	6.78±0.62	6.60±0.56#	6.64±0.61*	1441.96	0.00
control group	6.83±0.51	6.80±0.49	6.81±0.52	2212.71	0.00

Note: #p<0.05 reveals the middle test remarkably outperforming the ; *p<0.05 shows the posttest notably outperforming the pretest.

Analysis of muscle strength test result

Table 3 reveals the significant differences in both static group and static＋dynamic group (F_1=757.04, F_2=836.22, p<0.001; F_1=861.07, F_2=795.79, p<0.001), but not remarkable differences in the posteriori test. The dynamic group achieves the notable difference (F_1=1008.80, F_2=868.35, p<0.001), the middle test (235.92±22.31*nm*, 127.85±14.10*nm*) significantly outperforms the pretest (219.82±28.10*nm*, 119.64±14.98*nm*), and the *Cohen's d* 0.63 and 0.56, respectively, shows the medium effect size. The posttest (234.67±22.05*nm*, 127.42±13.75*nm*) remarkably outperforms the pretest, and the *Cohen's d* 0.59 and

0.54, respectively, reveals the medium effect size. Similarly, the dynamic＋static group reaches the notable differences (F_1=1033.04, F_2=945.96, p<0.001), the middle test (236.67±22.05*nm*, 127.71±13.45*nm*) significantly outperforms the pretest (219.83±26.48*nm*, 120.27±15.17*nm*), and the *Cohen's d* 0.69 and 0.52, respectively, reveals the medium effect size. The posttest (237.46±21.74*nm*, 129.45±12.82*nm*) remarkably outperforms the pretest, and the *Cohen's d* 0.73 and 0.65, respectively, presents the medium effect size. Furthermore, the control group does nto appear notable differences in the posteriori test.

Table 3: Isokinetic strength test result *(nm)*

	M±SD						F_1	*p*	F_2	*p*
	pretest		middle test		posttest					
	quadriceps femur muscles	hamstring tendon	quadriceps femur muscles	hamstring tendon	quadriceps femur muscles	hamstring tendon	quadriceps femur muscles		hamstring tendon	
static group	220.34 ± 26.12	120.13 ± 15.05	219.56 ± 26.52	119.71 ± 13.61	218.32 ± 26.20	119.45 ± 12.95	757.04	0.00	836.22	0.00
static ＋ dynamic group	222.00 ± 27.59	120.66 ± 14.41	221.95 ± 27.32	119.60 ± 13.98	222.56 ± 27.86	121.84 ± 14.30	861.07	0.00	795.79	0.00
dynamic group	219.82 ± 28.10	119.64 ± 14.98	235.92 ± 22.31#	127.85 ± 14.10#	234.67 ± 22.05*	127.42 ± 13.75*	1008.80	0.00	868.35	0.00
dynamic ＋ static group	219.83 ± 26.48	120.27 ± 15.17	236.67 ± 22.05#	127.71 ± 13.45#	237.46 ± 21.74*	129.45 ± 12.82*	1033.04	0.00	945.96	0.00
control group	215.34 ± 26.97	118.68 ± 14.57	215.56 ± 28.50	118.42 ± 14.80	216.09 ± 27.63	118.22 ± 15.01	787.65	0.00	873.48	0.00

Note: #p<0.05 presents the middle test significantly outperforming pretest, *p<0.05 reveals the posttest remarkably outperforming the pretest.

Discussion

Effects of stretching strategies on power

In terms of power, the pretest, middle test, and posttest performance among the gorups appears distinct reaction. The middle test of the static group is significantly lower than the pretest, and the posttest of the static+dynamic group is remarkably higher than the pretest, revealing that the power, after the practice of static stretching, is notably lower than it before stretching, and recovers after the rest. Nevertheless, the power, after dynamic stretching, is higher than it before static stretching. Such results support the negative effect (Matsuo *et al.*, 2013) of static stretching on power performance and the gain effect (Donti, Tsolakis, & Bogdanis, 2014) of dynamic stretching on power performance. The middle test and the posttest of the dynamic group outperform the pretest to further verify the enhancement of dynamic stretching on power performance. The dynamic＋static group could remain the gain effect of dynamic stretching on power, but the data reveal that the power standard is slightly reduced after static stretching. It also proves the negative effect of static stretching on power.

Young and Elliot (2001) indicated that in the centrifugation process of stretch-shortening cycle (SSC) of static stretching, the elastic energy stored in the muscle tendon unit would be released. Although the muscle stiffness might be maintained, the agonist contraction would appear delay effect. Previous research (Akagi, & Takahashi, 2013) proved that static stretching could acutely reduce the stiffness of plantar flexors, triceps surae, and hamstring tendons in muscle-tendon complex. Tendon tissue is an organ to generate speed, and the major function of tendon complex is to generate high-efficiency work. Proprioceptive receptor (e.g. Golgi tendon organ) mostly locates in tendons to perceive the change of tone. When muscle-tendon complex perceives over traction, autogenic inhibition would be generated to result in the decrease in recruitment ability of motor unit, weaken muscle nerve impulse or reflex sensitivity, and further reduce muscle power output. According to past research, it was discovered that the delay of agonist contraction, the decrease in stiffness of muscle-tendon complex, and the motor nerve activity inhibition are the factors in the acute reduction of power caused by static stretching.

In the comparison among the static+dynamic group, the dynamic＋static group, and the dynamic group, it is discovered that the power growth rate (4.69%) of the static+dynamic group is higher than it of the dynamic group (4.64%) and the dynamic+static group (4.31%), and the static+dynamic group shows the largest acute effect on power. It might because dynamic stretching could enhance physical perception (Fletcher, 2010), increase nerve conduction ability, and further enhance muscle contraction speed to promote athletes' response and agility, could effectively increase the core temperature of body (Congyi, & Chunzhi, 2001) to reduce viscosity of muscle and increase muscle contraction effectiveness so that the vertical jump is smoother, and could facilitate synovial capsule secreting more synovial fluid to smoothen joint motion and enhance agility to partially cancel out the power reduction caused by static stretching. Such conclusions are supported by Taylor *et al.* (2009) and Stewart *et al.* (2007). As a result, static+dynamic stretching could be adopted for warm-up before power training.

Effects of stretching strategies on speed

The stretching effect of the sprint static group does not appear significant differences, while the posttest of the static+dynamic group outperforms the pretest, showing no remarkable effect of static stretching on speed performance. However, the dynamic stretching presents positive effects. Short-distance speed standard is not affected by static stretching possibly because static stretching could acutely enhance the effect of joint motion; in spite that it could negative affect the explosive muscle strength for speed (Zili & Yuan, 2015). The larger running stride is therefore generated and the short-distance acceleration is smoothly executed to promote dash ability and cancel out the effect of static stretching on power decrease. Furthermore, other variables, including static stretching strength, duration, and repeat times, might be correlated. In comparison with past research (Rogan *et al.*, 2013), static stretching with different experimental variables resulting in the acute effect on speed performance is still controversial. The remarkable effect of static stretching on speed therefore could be regarded as the evidence of static stretching without negative effects.

The middle test and the posttest of the dynamic group and the dynamic＋static group notably outperform the pretest to further prove the positive effect of dynamic stretching on speed performance. Due to the effects of oxygen transport system and respiratory system as well as insufficient oxygen supply for body during sprint, glycogen and glucose, through anaerobic glycolysis, generate pyruvic acid, which is largely transformed into lactate under the catalysis of lactate dehydrogenase. Lactate, being a strong acid, would reduce the working ability of body when accumulating too much; the generation of lactate therefore is the critical key in obstructing the enhancement of speed. In the comparison of not having stretching (sit still for 5min) and stretching with 10min lactate threshold load density in past research (Laufs & Adam, 2012), the exercise with 80% maximal oxygen consumption was continued for 5min; the results showed notably lower blood lactate (4.62±0.84*mmol*/*L*) of the stretching group than the sit-still group (6.48±1.67*mmol*/*L*). Accordingly, it was inferred that dynamic stretching with short-time load could alleviate the accumulation of blood lactate to put off exercise-induced fatigue.

According to the data, the static＋dynamic group enhances the speed 2.50%, the dynamic group enhances the speed 4.56%, and the dynamic＋static group enhances 2.10%. The dynamic group appears the higher enhancement of speed than other groups, revealing that short-time rest after dynamic stretching could better enhance speed performance. Stewart *et al.* (2007) proposed that the 40*m* sprint performance of the dynamic＋static group was relatively slow. Sim *et al.* (2009) reported that the subjects did not reduce the repeat sprint ability in the test after dynamic or static＋dynamic stretching. However, static stretching would reduce athletes' 20*m* repeat sprint ability when being preceded after dynamic stretching or before the test. Such a result is not completely identical to this study. It reveals in this study that static stretching, before/after dynamic stretching or before the test, would not affect the sprint performance and could even remarkably enhance the performance. Such a result requires more evidence.

Effects of stretching strategies on muscle strength

Muscle strength refers to muscles or muscle group being able to generate the maximal strength under specific speed (Kraemer, & Knuttgen, 2015). The results reveal that static stretching would weaken/reduce muscle strength; but, the changes in the statistical test do not appear significance, showing that short-time static stretching would not obviously change muscle strength. Zakas *et al.* (2006) proposed in the experiment that 30~60*s* static stretching would not reduce muscle strength performance, while static stretching continued for 5~8*min* would notably reduce the muscle strength performance. Apparently, stimulation time is a primary factor in the acute effect of static stretching on muscle strength. Short-time static stretching would not affect muscle strength performance. Such a finding is extremely important in real training. In this case, athletes could apply various short-time static stretching programs before the maximal strength training to reduce the risk in the training. Furthermore, the middle test and the posttest of the static+dynamic group do not appear significant changes, but the muscle strength in the middle test was lower than it in the pretest. The muscle strength in the posttest is enhanced, revealing the reinforcement effect of dynamic stretching on muscle strength performance.

The middle test and the posttest of the dynamic group and the dynamic＋static group significantly outperform the pretest, proving the gain effect of dynamic stretching on muscle strength. Muscle fiber is the active organ to generate strength. Past research (Weir, Tingley, & Elder, 2005) revealed that the maximal muscle strength changes were caused by the changes of the mechanical factor of muscle fiber (i.e. changes of muscle stiffness), rather than the activation changes of motor unit (i.e. changes of nervous factor). In this case, the gain effect of dynamic stretching on muscle strength performance might be resulted from the changes of the mechanical characteristics of muscle fiber. Static stretching would also change the mechanical characteristics of muscle fiber, with differences. After long-time static stretching, tendon unit would be more compliant to reduce the stiffness and result in the inhibition of nervous sensitivity and the decreasing ability of nerve conduction driving muscles to further obstruct the muscle strength performance. Dynamic stretching appears exactly the opposite. Dynamic stretching therefore could enhance the development of muscle strength.

The comparison shows that the muscle strength growth rate of the dynamic＋static group (quadriceps femur muscles 8.02%, hamstring tendon 7.63%) is better than it of the dynamic group (quadriceps femur muscles 6.76%, hamstring tendon 6.50%). It might be the reason that static stretching after certain load of dynamic stretching could better benefit the body keeping the temperature to generate more positive effects on the muscle strength test, compared to sitting still and rest. Interestingly, the maximal gain of power and muscle strength is distinct, in spite of the same muscle fitness performance, possibly because of different motor patterns. Isokinetic strength test is applied to test muscle strength, i.e. test under steady motion but changeable resistance. Limbs could not generate motion acceleration that they appear fewer relations to motion nerve activation. In terms of power test, which is closely related to acceleration time, preceding dynamic stretching after static stretching allows keeping motion nerve activity to appear better gain effects on power. It is therefore inspired that the stretching order should be properly adjusted according to the training objective.

Conclusion

Static stretching presents negative effects on power performance, dynamic stretching shows gain effects on power performance, and static+dynamic stretching is the best stretching strategy for power training. Static stretching does not reveal remarkable effects on speed performance, dynamic stretching could notably enhance speed performance, and dynamic stretching is the best stretching strategy for speed training. Static stretching does not appear significant effects on muscle strength, dynamic stretching reveals remarkably positive effects on muscle strength performance, and dynamic and static stretching is the best stretching strategy for muscle strength training.

Suggestions

Due to manpower and finance, the sample size in this study is rather small. The conclusion requires more comprehensive tests and experimental data in the future research. The conclusion is simply the reference for training practice. Besides, 3 sets of shorter-time stretching (30s for each set) are preceded in this study. The mutual effects of different stretching time and stretching strategies on power, speed, and muscle strength could be designed and discussed in the future. Finally, the muscle strength is tested under 30°/s angular velocity in this study to examine the effect of different stretching strategies on the maximal muscle strength. Other angular velocity could be selected for muscle strength tests in the future; and, data of power-time curve parameters and myoelectric activities could be collected with more evidence for the study on muscle strength.

References

Akagi, R., & Takahashi, H. (2013). Acute effect of static stretching on hardness of the gastrocnemius muscle. *Medicine and Science in Sports and Exercise*, *45*, 1348-1354. doi:10.1249/mss.0b013e3182850e17

Beckett, J.R., Schneiker, K.T., Wallman, K.E., Dawson, B.T., & Guelfi, K.J. (2009). Effects of static stretching on repeated sprint and change of direction performance. *Medicine and Science in Sports and Exercise*, *41*, 444-450. doi: 10.1249/mss.0b013e3181867b95

Chattong, C., Brown, L.E., Coburn, J.W., & Noffal, G.J. (2010). Effect of a dynamic loaded warm-up on vertical jump performance. *Journal of Strength and Conditioning Research*, *24*, 1751-1754. doi: 10.1519/jsc.0b013e3181ddf665

Congyi, C., & Chunzhi, D. (2001). The significance of stretching exercise in exercise and fitness. *Sports Research Review*, *12*, 83-87. doi: 10.6162/SRR.201903_148.0001

Curry, B.S., Chengkalath, D., Crouch, G.J., Romance, M., & Manns, P.J. (2009). Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women. *Journal of Strength and Conditioning Research*, *23*, 1811-1819. doi: 10.1519/jsc.0b013e3181b73c2b

Donti, O., Tsolakis, C., & Bogdanis, G.C. (2014). Effects of baseline levels of flexibility and vertical jump ability on performance following different volumes of static stretching and potentiating exercises in elite gymnasts. *Journal of sports science and medicine*, *13*, 105-113. doi: 10.1177/1754337113493083

Fletcher, I.M. (2010). The effect of different dynamic stretch velocities on jump performance. *European Journal of Applied Physiology*, *109*, 491-498. doi: 10.1007/s00421-010-1386-x

Fletcher, I.M., & Jones, B. (2004). The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *Journal of Strength and Conditioning Research*, *18*, 885-888. doi: 10.1519/00124278-200411000-00035

Gabbett, T.J., Sheppard, J.M., Pritchard-Peschek, K.R., Leveritt, M.D., & Aldred, M.J. (2008). Influence of closed skill and open skill warm-ups on the performance of speed, change of direction speed, vertical jump, and reactive agility in team sport athletes. *Journal of Strength and Conditioning Research*, *22*, 1413-1415. doi: 10.1519/jsc.0b013e3181739ecd

Gelen, E., Dede, M., Bingul, B.M., Bulgan, C., & Aydın, M. (2012). Acute effects of static stretching, dynamic exercises, and high volume upper extremity plyometric activity on tennis serve performance. *Journal of Sports Science and Medicine*, *11*, 600-605. doi: 10.1055/s-0032-1327645

Haddad, M., Dridi, A., Chtara, M., Chaouachi, A., Wong. D.P., Behm, D., Chamari, K. (2014). Static stretching can impair explosive performance for at least 24 hours. *Journal of Strength and Conditioning Research*, *28*,140-146. doi: 10.1519/jsc.0b013e3182964836

Kistler, B.M., Walsh, M.S., Horn, T.S., & Cox, R.X. (2010). The acute effects of static stretching on the sprint performance of collegiate men in the 60-m and 100-m dash after a dynamic warm-up. *Journal of Strength and Conditioning Research*, *24*, 2280-2284. doi: 10.1519/JSC.0b013e3181e58dd7

Kraemer, W.J., & Knuttgen, H.G. (2015). Strength training basics: designing workouts to meet patients' goals. *Physician and Sports Medicine*, 39-45. doi: 10.3810/psm.2003.08.457

Laufs, U., Adam, O. (2012). Acute effects of statins.Journal of the American College of Cardiology, *59*, 71-73. doi: 10.1016/j.jacc.2011.08.063

Lowery, R.P., Joy, J.M., Brown, L.E., Oliveira de Souza, E., Wistocki, D.R., Davis, G.S., Naimo, M.A., Zito, G.A., & Wilson, J.M. (2014). Effects of static stretching on 1-mile uphill run performance. *Journal of Strength and Conditioning Research*, *28*, 161-167. doi: 10.1519/jsc.0b013e3182956461

Matsuo, S., Suzuki, S., Iwata, M., Banno, Y., Asai, Y., Tsuchida, W., & Inoue, T. (2013). Acute effects of different stretching durations on passive torque, mobility, and isometric muscle force. *Journal of Strength and Conditioning Research*, *27*, 3367-3376. doi: 10.1519/jsc.0b013e318290c26f

Mcmillian, D.J., Moore, J.H., Hatler, B.S., & Taylor, D.C. (2006). Dynamic vs. static-stretching warm up: the effect on power and agility performance. *Journal of Strength and Conditioning Research*, *20*, 492-499. doi: 10.1519/00124278-200608000-00006

Miller, M.G. (1998). Sport stretch. *Journal of Athletic Training*, *33*, 185.

Nakamura, M., Ikezoe, T., Takeno, Y., & Ichihashi, N. (2013). Time course of changes in passive properties of the gastrocnemius muscle-tendon unit during 5 min of static stretching. *Manual Therapy*, *18*, 211-215. doi: 10.1016/j.math.2012.09.010

Rogan, S., Wüst, D., Schwitter, T., & Schmidtbleicher, D. (2013). Static stretching of the hamstring muscle for injury prevention in football codes: a systematic review. Asian Journal of Sports Medicine, *4*, 1-9. doi: 10.5812/asjsm.34487

Serra, A.J., Silva, J. Jr, Marcolongo, A.A., Manchini, M.T., Oliveira, J.V., Santos, L.F., Rica, R.L., & Bocalini, D.S. (2013). Experience in resistance training does not prevent reduction in muscle strength evoked by passive static stretching. *Journal of Strength and Conditioning Research*, *27*, 2304-2308. doi: 10.1519/jsc.0b013e31827969eb

Sim, A.Y., Dawson, B.T., Guelfi, K.J., Wallman, K.E., & Young, W.B. (2009). Effects of static stretching in warm-up on repeated sprint performance. *Journal of Strength and Conditioning Research*, *23*, 2155-2162. doi: 10.1519/jsc.0b013e3181b438f3

Simic, L., Sarabon, N., & Markovic, G. (2012). Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scandinavian journal of medicine and science in sports*, *23*, 131-148. doi: 10.1111/j.1600-0838.2012.01444.x

Stewart, M., Adams, R., Alonso, A., Van Koesveld, B., & Campbell, S. (2007). Warm-up or stretch as preparation for sprint performance?. *Journal of Science and Medicine in Sport*, *10*, 403-410. doi: 10.1016/j.jsams.2006.10.001

Taylor, K.L., Sheppard, J.M., Lee, H., & Plummer, N. (2009). Negative effect of static stretching restored when combined with a sport specific warm-up component. *Journal of Science and Medicine in Sport*, *12*, 657-661. doi: 10.1016/j.jsams.2008.04.004

Weir, D.E., Tingley, J., & Elder, G.C. (2005). Acute passive stretching alters the mechanical properties of human plantar flexors and the optimal angle for maximal voluntary contraction. European *Journal of Applied Physiology*, *93*, 614-623. doi: 10.1007/s00421-004-1265-4

World Medical Association. (2001). World Medical Association declaration of Helsinki: Ethical principles for medical research involving human subjects. *Bulletin of the World Health Organization*, *79*, 373-374. doi: 10.1007/BF02811094

Young, W., & Elliott, S. (2001). Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jumping performance. *Research Quarterly for Exercise and Sport*, *72*, 273-279. doi: 10.1080/02701367.2001.10608960

Zakas, A., Balaska, P., Grammatikopoulou, M.G., Zakas, N., & Vergou, A. (2005). Acute effects of stretching duration on the range of motion of elderly women. *Journal of Bodywork and Movement Therapies*, *9*, 270-276. doi: 10.1016/j.jbmt.2004.10.006

Zakas, A., Doganis, G., Galazoulas, C., & Vamvakoudis, E. (2006). Effect of acute static stretching duration on isokinetic peak torque in pubescent soccer players. *Pediatric Exercise Science*, *18*, 252-261. doi: 10.1123/pes.18.2.252

Zakas, A., Doganis, G., Papakonstandinou, V., Sentelidis, T., & Vamvakoudis, E. (2006). Acute effects of static stretching duration on isokinetic peak torque production of soccer players. *Journal of Bodywork and Movement Therapies*, *10*, 89-95. doi: 10.1016/j.jbmt.2005.04.007

Zili, J., & Yuan, L. (2015). Research progress on the acute effects of static stretching: role, mechanism and enlightenment. *China Sport Science and Technology*, *51*, 3-13. doi: 1002-9826(2015)02-0003-11