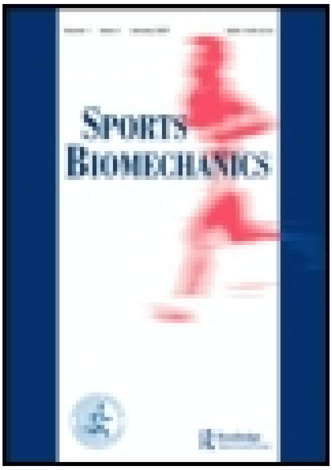

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An electromyographic comparison of a modified version of the plank with a long lever and posterior tilt versus the traditional plank exercise

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An electromyographic comparison of a modified version of the plank with a long lever and posterior tilt versus the traditional plank exercise

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Abstract
The purpose of the study was to compare core muscle activation of the tradition prone plank with a modified version performed with a long-lever and posterior-tilt using surface electromyography. To further determine if a specific component of this modified plank was more effective than the other in enhancing muscle activity, the plank with a long lever and the plank with a posterior pelvic tilt were studied individually. Nineteen participants performed all four variations of the plank for 30 seconds in a randomized order with 5-minute rest between exercise bouts. Compared to the traditional prone plank, the long-lever posterior-tilt plank displayed a significantly increased activation of the upper rectus abdominis ($p < 0.001$), lower abdominal stabilizers ($p < 0.001$), and external oblique ($p < 0.001$). The long-lever plank showed significantly greater activity compared to the traditional plank in the upper rectus abdominis ($p = 0.015$) and lower abdominal stabilizers ($p < 0.001$), while the posterior tilt plank elicited greater activity in the external oblique ($p = 0.028$). In conclusion, the long-lever posterior-tilt plank significantly increases muscle activation compared to the traditional prone plank. The long-lever component tends to contribute more to these differences than the posterior-tilt component.

Keywords: *Core stability, core performance, abdominal muscles, long-lever posterior-tilt plank*

Introduction

The prone plank is a popular fitness exercise that has been advocated as beneficial both for rehabilitation programs (D'Amico, Betlach, Senkarik, Smith, & Voight, 2007) as well as physical conditioning routines (Hofstetter, Mader, & Wyss, 2011) Beneficial effects of the prone plank are thought to be related to an improved core stability, defined as "the ability of passive and active stabilizers in the lumbopelvic region to maintain appropriate trunk and hip posture, balance and control during both static and dynamic movement" (Reed, Ford, Myer, & Hewett, 2012). Theoretically, enhanced core stability allows the core musculature

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to resist applied external forces and maintain postural control in response to a perturbation. The enhanced core stability may therefore translate into better functional performance.

Traditionally, performance of the prone plank involves assuming a push-up position with the forearms on the ground and the elbows positioned directly beneath the glenohumeral joints, spaced shoulder width apart. Lehman, Hoda, & Oliver (2005) showed that the prone plank elicited 29.5%, 26.6%, 44.6% and 4.98% of maximum voluntary contraction (MVC) in the internal oblique, rectus abdominis, external oblique and erector spinae musculature, respectively, in a group of resistance-trained participants. Recently, however, its transfer to sports skills has been called into question by some researchers (Parkhouse & Ball, 2011; Shinkle, Nesser, Demchak, & McMannus, 2012). It is possible that the prone plank does not sufficiently challenge the neuromuscular system in highly fit individuals, thereby limiting transfer to dynamic performance. As a more challenging alternative, several strength coaches have promoted modifying the traditional prone plank so that it is performed with a long lever and posterior tilt (Schoenfeld & Contreras, 2013). Performance of the long-lever posterior-tilt plank involves actively contracting the gluteal musculature to bring about a posterior pelvic tilt. The elbows are positioned further toward the head and closer together than in the prone plank, which increases lever arm length and reduces the base of support. In combination, these factors conceivably enhance recruitment of the core musculature and thus may improve sports performance even in well-trained athletes.

The posterior tilting mechanism, created by the force coupling of the hip extensors (gluteus maximus and hamstrings) and the abdominal musculature (rectus abdominis and external oblique), is believed to have a particularly strong influence on core muscle activity (Neumann, 2010). A supine posterior pelvic tilt isometric hold has been shown to elicit 12.2%, 15.9%, 26.3%, 7.3%, and 5.6% of MVC in the lower abdominal stabilizers, upper rectus abdominis, external oblique, erector spinae, and multifidus musculature, respectively, in a study involving healthy participants (Vezina & Hubley-Kozey, 2000). These percentages of activation were approximately duplicated in a subsequent study involving participants with low back pain (12.4%, 12.9%, 29.7%, 6.5%, and 4.2% of MVC in the lower abdominal stabilizers, upper rectus abdominis, external oblique, erector spinae, and multifidus, respectively) (Hubley-Kozey & Vezina, 2002). Moreover, performing hip extension exercise in posterior pelvic tilt has been shown to lead to increased activation in the gluteus maximus, rectus abdominis, external oblique, and internal oblique, but not the multifidus or iliocostalis, when compared to performing hip extension in anterior pelvic tilt or neutral pelvic positions (Queiroz, Cagliari, Amorim, & Sacco, 2010). Performing double straight leg lifts in posterior pelvic tilt has been shown to lead to increased activation in the upper rectus abdominis and lower abdominal stabilizers, but not the rectus femoris, when compared to performing double straight leg lifts in anterior pelvic tilt or neutral pelvic positions (Workman, Docherty, Parfrey, & Behm, 2008).

The purpose of the current study was to examine if differences exist in core muscle activity between the traditional prone plank and the long-lever posterior-tilt plank as determined by surface electromyography (EMG). Based on the aforementioned research, our first hypothesis was that the long-lever posterior-tilt plank would elicit significantly greater muscle activity versus the traditional prone plank. To further determine if a specific component of the long-lever posterior-tilt plank was more effective than the other in enhancing muscle activity, the plank with a long lever and the plank with a posterior pelvic tilt were studied individually by EMG. Our second hypothesis was that the plank with a posterior pelvic tilt would have a greater effect on muscle activity compared to the plank with a long lever, and thus provide a greater contribution to the postural stabilizing demands of the long-lever posterior-tilt plank.

Methods

Participants

Nineteen male participants between the ages of 18 and 35 were recruited as a convenience sample from a university population to participate in this study (mean ± *SD* age: 23.3 ± 4.0 years; height: 178.8 ± 7.4 cm; body mass: 80.0 ± 8.2 kg; training experience: 5.8 ± 4.2 years). All participants were experienced with resistance training, defined as lifting weights for a minimum of two days a week for one year or more. Participants also had similar experience performing abdominal exercise. Inclusion criteria required participants to read and speak English and pass a physical activity readiness questionnaire (PAR-Q). Those receiving care for any back or abdominal related orthopedic issues at the time of the study were excluded from participation. Each subject provided written informed consent prior to participation. The research protocol was approved by the Institutional Review Board at Lehman College, Bronx, NY.

Procedure

Following consent, participants were prepped for testing by wiping the skin in the desired areas of electrode attachment with an alcohol swab to ensure stable electrode contact and low skin impedance. Any visible body hair in these areas was abraded and shaved prior to preparation. After preparation, self-adhesive disposable silver/silver chloride pre-gelled dual snap surface bipolar electrodes (Noraxon Product #272, Noraxon USA Inc., Scottsdale, AZ) with a diameter of 1 cm and an inter-electrode distance of 2 cm were attached parallel to the fiber direction of the upper rectus abdominis, lower abdominal stabilizers (which measures a blending of lower rectus abdominis, transverse abdominis, and internal oblique activity) (Marshall & Murphy, 2005), external oblique, and erector spinae muscles. A neutral reference electrode was placed over the bony process of the mid-spine. These methods were consistent with the recommendations of SENIAM (Surface EMG for Non Invasive Assessment of Muscles) (SENIAM project, 2005). After all electrodes were secured with medical adhesive tape, a quality check was performed to ensure EMG signal validity.

Instrumentation

Raw EMG signals were collected at 2,000 Hz by a Myotrace 400 EMG unit (Noraxon USA Inc., Scottsdale, AZ), and filtered by an eighth-order Butterworth band-pass filter with cutoffs of 20–500 Hz. Data were sent in real time to a computer via Bluetooth and recorded and analyzed by MyoResearch XP Clinical Applications software (Noraxon USA Inc., Scottsdale, AZ). Signals were rectified by root mean square algorithm and smoothed in real time. The mean EMG values during each 30-s static action were subsequently compared in the statistical analysis.

Maximal voluntary isometric contraction

Isometric MVC data were obtained for each muscle tested by performing resisted isometric actions for the core musculature similar to that described by Lehman et al. (2005). After an initial warm up consisting of 5 min of light cardiovascular exercise and slow dynamic stretching in all three cardinal planes, participants performed two different bouts against manual resistance: (1) a trunk curl up and twist to maximally recruit the upper rectus abdominis, lower abdominal stabilizers, and external oblique muscles, and (2) an isometric prone trunk extension to maximally recruit the erector spinae. For each bout, participants were asked to slowly increase the force of the contraction so as to reach a maximum effort after approximately 3 s. Participants then held the maximal contraction for 3 s before slowly reducing force over a final period of 3 s. This procedure was repeated once for each muscle following a 60-s rest interval and the highest MVC value was used for normalization purposes. The mean EMG values for each muscle were expressed as a percentage of MVC.

Exercise description

To ensure proper exercise performance, participants were provided with a familiarization session where the primary investigator, a certified trainer, gave detailed verbal instruction of each plank variation. Instruction was supplemented with video demonstration of the respective movements. Following instruction, participants were asked if they understood the performance of each movement and any remaining questions were answered with respect to exercise performance. Descriptions and photos of the exercise variations are provided in Table I and Figure 1a–d, respectively.

After completion of the familiarization session, participants were asked to perform a given variation of the plank exercise. Participants held each plank position for 30 s. Verbal encouragement and coaching were provided during performance to ensure that exercise was carried out in the prescribed manner. Participants were then given a 5-min rest period and subsequently asked to perform another variation of the plank. This protocol continued until all four plank variations were performed. The order of performance for each variation was randomly assigned utilizing a Latin Square approach to minimize any potential confounding effects of exercise sequence on results.

Table I. Description of plank variations.

Exercise variation	Description
Traditional prone plank	Lie face-down with fists on the floor, feet shoulder width apart, and spine and pelvis in a neutral position. The elbows are spaced shoulder width apart directly below the glenohumeral joint. Lift the body up on the forearms and toes, keeping the body as straight as possible. Maintain this position for 30 s.
Long-lever plank	Lie face-down with fists on the floor, feet shoulder width apart, and spine and pelvis in a neutral position. The elbows are spaced 6 inches apart at nose level. Lift the body up on the forearms and toes, keeping the body as straight as possible. Maintain this position for 30 s.
Posterior-tilt plank	Lie face-down with fists on the floor, feet shoulder width apart, and spine and pelvis in a neutral position. The elbows are spaced shoulder width apart directly below the glenohumeral joint. The gluteal muscles are contracted as strongly as possible while attempting to draw the pubic bone toward the belly button and the tailbone toward the feet. Lift the body up on the forearms and toes, keeping the body as straight as possible. Maintain this position for 30 s.
Long-lever posterior-tilt plank	Lie face-down with fists on the floor, feet shoulder width apart, and spine and pelvis in a neutral position. The elbows are spaced 6 inches apart at nose level. The gluteal muscles are contracted as strongly as possible while attempting to draw the pubic bone toward the belly button and the tailbone toward the feet. Lift the body up on the forearms and toes, keeping the body as straight as possible. Maintain this position for 30 s.

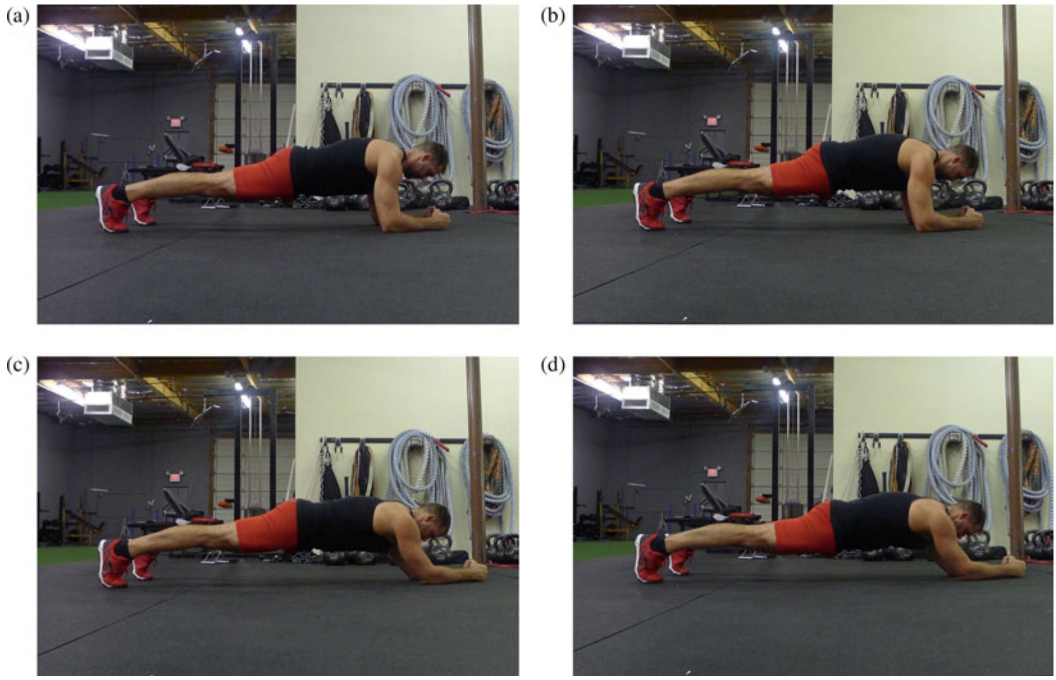

Figure 1. Variations of plank exercise: traditional prone plank (a), posterior tilt plank (b), long-lever plank (c), and long-lever posterior tilt plank (d).

Statistical analysis

A 4 (muscles) × 4 (exercise variations) two-way ANOVA with repeated measures on the latter factor was utilized to compare the performance of each exercise variation on the assessed muscles. The exercise variations were the traditional prone plank, long lever plank, plank with a posterior pelvic tilt, and the long lever plank with a posterior pelvic tilt; the muscles assessed were the erector spinae, upper rectus abdominis, lower abdominal stabilizers, and external oblique abdominis. The dependent variable was normalized EMG values. Because the sphericity assumption was violated ($p < 0.01$), the Greenhouse-Geisser correction was applied to correct for violations of the sphericity assumption. Effect size (partial η^2) and observed power statistics were computed for significant main effects. Post-hoc comparisons were conducted using the Bonferroni procedure. Statistical significance was set at $p \leq 0.05$. Statistical analysis was carried out using SPSS 16 (SPSS Inc., Chicago, IL).

Results

Based on the Greenhouse-Geisser correction procedure, a significant ($p < 0.05$) interaction between exercise variations and muscles was found ($F_{6.59,158.34} = 8.96$; $p < 0.001$; $\eta_p^2 = 0.27$; $1-\beta = 1.00$; see Table II). When comparing the four different muscles across exercise variations, findings can be summarized as follows: (a) for the erector spinae, there were no significant differences across exercise variations (Figure 2a, b) for the upper rectus abdominis, significantly greater activity was noted for the plank with a long lever and long-lever posterior-tilt plank versus the traditional prone plank (Figure 2b, c) for the lower

Table II. Summary of EMG values across muscles and exercise variations expressed as percent MVC.

	Traditional	Long lever	Posterior tilt	Long lever posterior tilt
Erector spinae	4.84 ± 2.27	5.74 ± 3.25	6.77 ± 3.19	7.10 ± 4.27
Upper rectus abdominis	27.26 ± 20.60	90.47 ± 64.23*§	54.58 ± 34.55	109.74 ± 66.30*§
Lower abdominal stabilizers	37.84 ± 25.83	121.05 ± 52.45*§	81.21 ± 46.12*	153.89 ± 88.43*§
External oblique	50.21 ± 36.15	101.79 ± 68.80*	110.79 ± 66.30*§	148.74 ± 70.14*§

Mean ± *SD*.
*Significantly different from erector spinae ($p < 0.05$).
§Significantly different from the traditional plank condition ($p < 0.05$).

abdominal stabilizers, significantly greater activity was noted for the plank with a long lever and long-lever posterior-tilt plank versus the traditional prone plank; also, significantly greater activity was noted for the long-lever posterior-tilt plank versus the plank with a posterior pelvic tilt (Figure 2c, and d) for the external obliques, significantly greater activity was noted for the plank with a posterior pelvic tilt and long-lever posterior-tilt plank versus the traditional prone plank (Figure 2d).

Differences in EMG activity were also found when comparing the four exercise conditions across muscles. Bonferroni post-hoc analyses indicated that the erector spinae was less active than any of the other three muscles during the long-lever plank and long-lever posterior-tilt plank exercises ($p_s < 0.001$). For the plank with a posterior pelvic tilt, erector spinae was less

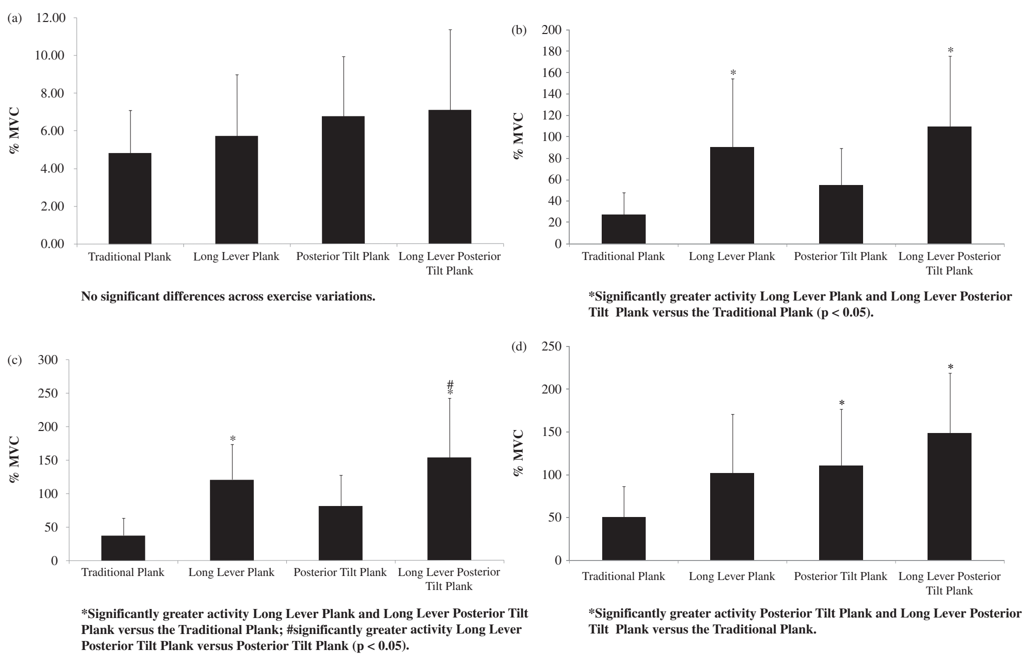

Figure 2. Normalized EMG activity of erector spinae (a), upper rectus abdominis (b), lower abdominal stabilizers (c), and lower external oblique (d) across plank variations.

active than the lower abdominal stabilizers ($p < 0.001$) and external oblique ($p < 0.001$). Differences between muscles were not found for the traditional prone plank exercise.

Discussion and implications

Our first hypothesis was supported in that the long-lever posterior-tilt plank elicited significantly greater muscle activity versus the traditional prone plank for all muscles with the exception of the erector spinae (ES). However, our second hypothesis was not supported in that the plank with a long lever elicited significantly greater muscle activity in the lower abdominal stabilizers versus the plank with a posterior pelvic tilt, while no significant differences were seen between these variations in the other muscles evaluated. When examining the mean values in Table II the long-lever posterior-tilt plank elicited the highest mean EMG values for all muscles and represented the most difficult of the exercise variations examined. However, enacting a longer lever tended to have a greater effect for increasing the muscular demands of the long-lever posterior-tilt plank exercise versus enacting a posterior pelvic tilt, although the two variations appear to be synergistic in optimizing core activity. Therefore, when considering postural stabilizing demands the appropriate progression for practitioners would be as follows: the traditional prone plank, plank with a posterior pelvic tilt, plank with a long lever, and then the long-lever posterior-tilt plank.

This is the first study to show that a modified version of the traditional plank employing a long lever and posterior tilt significantly and markedly increases muscle activity in the rectus abdominis and external oblique as compared to the traditional prone plank. These muscles are considered essential to core stability and provide support for the lumbar spine during activities of daily living (Lehman, 2006). Importantly, the modifications associated with the long-lever posterior-tilt plank are easy to implement and require no special equipment, making the exercise a highly accessible and convenient option for the general population. Similar to the results of Lehman et al. (2005), normalized EMG activity of the rectus abdominis and external oblique during the traditional prone plank was modest in resistance-trained individuals. The low values obtained in these muscles indicate that the participants were not significantly challenged by this exercise, at least for the duration of the 30-s bout employed in this study. These findings indicate that the traditional prone plank is more suitable for beginners or for rehabilitative purposes as opposed to those with ample training experience.

It is worthy of mention that considerable inter-individual variation was observed between participants for the muscles tested in the traditional prone plank. The minimum and maximum mean values for the erector spinae, upper rectus abdominis, lower abdominal stabilizers, and external oblique muscles were 2% and 9%, 7% and 83%, 2% and 89%, and 3% and 118%, respectively. Thus, even some well-trained individuals may benefit from the traditional plank, albeit to a much lesser extent than with the long-lever posterior-tilt plank and its variants. The mean erector spinae activity for the traditional prone plank, plank with a long lever, plank with a posterior pelvic tilt, and long-lever posterior-tilt plank was minimal (5%, 6%, 7%, and 7%, respectively). Based on these data, we can conclude that the erector spinae muscles are not required to sufficient degree, not even for co-contraction purposes, for trunk stability during the plank variations examined in this study. Although plank variations are typically employed for purposes of increasing core stability, it is important to realize that prone plank variations are "anti-extension" exercises that challenge the anterior core musculature (Schoenfeld & Contreras, 2011). Additional exercises would need to be prescribed for purposes of targeting the ES and developing "anti-flexion" stability, or the ability to resist flexion of the spinal column.

Contrary to our initial hypothesis, the plank with a long lever had a significantly greater effect on muscle activity compared to the plank with a posterior pelvic tilt. Apparently, increasing the distance between the elbows and toes during the plank exercise as we have done in this study produces a greater challenge to the core musculature than manipulating pelvic position. Future biomechanical research could examine the combinations of spinal and pelvic torque in the sagittal plane during the traditional prone plank, plank with a long lever, plank with a posterior pelvic tilt, and long-lever posterior-tilt plank to further elucidate the mechanisms contributing to the challenge on the core musculature between the different exercise variations.

The results of this study have a number of important practical implications. Panjabi (1992) defined segmental instability "as a significant decrease in the capacity of the stabilizing system of the spine to maintain the intervertebral neutral zones within the physiological limits so that there is no neurological dysfunction, no major deformity, and no incapacitating pain". Spinal instability is associated with reduced strength and endurance of the core musculature as well as altered recruitment of these muscles (Hibbs, Thompson, French, Wrigley, & Spears, 2008; van Dieen, Cholewicki, & Radebold, 2003). It is theorized that core muscle endurance, as opposed to maximal core strength, is the primary factor in the etiology of spinal instability and lower back pain for the general public (Lehman, 2006; McGill, 1998). Static core muscle endurance, in particular, is considered essential to carrying out everyday activities in a pain-free manner (McGill, 2007; McGill, 2010). Training to optimize static core endurance requires the performance of isometric exercise for durations of over 30 s (Faries & Greenwood, 2007). To this end, the traditional prone plank has been identified as a beneficial exercise for enhancing this fitness variable (Lehman, 2006). While the traditional prone plank could conceivably be effective in improving core endurance in untrained individuals, the principle of progressive overload dictates that bodily tissues must be repeatedly challenged over time to foster continued adaptation. The long-lever posterior-tilt plank can therefore be implemented as part of a progressive core training regimen to enhance spinal stability and potentially reduce the risk of low back pain as one acquires training experience.

Stability training has been used to treat patients with segmental instability, clinical instability, and chronic back pain (Biely, Smith, & Silfies, 2006). It remains questionable, however, as to whether such training is efficacious (Lederman, 2010). Research indicates that 90% of low back pain is nonspecific in nature, and that the causes of this type of back pain are nebulous (Cissik, 2011). This would seem to cast doubt on the ability of core stability exercise to improve nonspecific low back pain. Furthermore, some researchers have suggested that progressively overloading the spine during core stability training is risky and it therefore should be reserved for performance-oriented goals rather than pain prevention (McGill, 2010). In consideration of these issues, the long-lever posterior-tilt plank may not be appropriate for those with clinical conditions related to the spine. It is conceivable that the long-lever posterior-tilt plank could be used as a strategy to improve pelvic awareness and kinesthesia; particularly to avoid excessive anterior pelvic tilt. Considering that it has been shown that 85% of males and 75% of females possess anterior pelvic tilt, this may be of significant importance (Herrington, 2011). Although it has been suggested that anterior pelvic tilt increases the stress on the lumbar spine (Jull & Janda, 1987), the condition is common within normal asymptomatic populations and research has failed to show an association between anterior pelvic tilt and low back pain (Nourbakhsh & Arab, 2002). Nevertheless, there is evidence that resistance and flexibility training help to improve lumbar alignment (Scannell & McGill, 2003), and therefore it is plausible that resistance and flexibility training could alter pelvic tilt angle. It has been suggested, however, that anterior pelvic tilt is advantageous in certain sports such as sprint running (Kritz & Cronin, 2008). More research is needed to elucidate whether pelvic alignment can be altered through resistance training; whether these changes lead to increases or decreases in back pain; and whether these changes positively or negatively affect athletic performance.

The long-lever posterior-tilt plank may be especially beneficial to athletes. A majority of athletic endeavors require the performer to maintain core stability during highly dynamic movements, often under highly loaded conditions (Hibbs et al., 2008). The rectus abdominis, in particular, is thought to play an important role in bracing the spine during pushing tasks or during the lifting of heavy loads, which are often relevant to sports performance (Hibbs et al., 2008). The sports of football, rugby, soccer, wrestling, and hockey, to name a few, all contain horizontal pushing components whereby increased anti-extension trunk stability could increase performance. Theoretically, increased lumbar and pelvic stability would prevent the core from buckling, thereby preventing potential injury while also allowing for the optimal transference of force from the ground to the opponent. A recent systematic review, however, showed only marginal improvements in athletic performance from core stability training while at the same time noting that a strong and stable core provides a necessary foundation for optimal execution of a variety of sporting movements (Reed et al., 2012). Future research should examine the potential relationship between the quality of performance in the long-lever posterior-tilt plank and higher force activities that challenge the ability of the trunk to resist flexion and the transfer to sports performance. There may be particular benefit of the long-lever posterior-tilt plank to the sport of powerlifting. Considering that pelvic and lumbar posture are inextricably linked in the standing position (Levine & Whittle, 1996), and that it has been suggested that excessive lumbar extension should be avoided at the end range of motion of a deadlift (Bird & Barrington-Higgs, 2010), the long-lever posterior-tilt plank may lead to improvements in deadlift performance via increased lockout power relating to a better ability to resist lumbopelvic deformation subsequent to stronger and more coordinated gluteal and abdominal musculature at end range of hip extension. Future research should examine the effects of the long-lever posterior-tilt plank on the deadlift exercise in the sport of powerlifting.

McGill (1998) contends that performing a posterior pelvic tilt during core exercise may increase the risk of spinal injury by preloading the annulus and posterior ligaments. It is not clear whether this would be a risk factor in those with healthy spines. To the authors' knowledge, no study to date has evaluated the effect of posterior tilt exercise on spinal injury in any population. Given the aforementioned theoretical rationale, however, it may be appropriate for individuals with existing disk-related issues, such as flexion-intolerance, to avoid this maneuver. In such cases, performing the plank with a long lever would seem to be a viable alternative as it has a greater effect on anterior trunk muscle activation without the associated risk to spinal structures.

Conclusions

The long-lever posterior-tilt plank offers a more challenging alternative to the traditional prone plank that results in markedly greater muscle activity of the core musculature. These findings would appear to have particular relevance for well-trained individuals given the low core muscle activity seen with the traditional prone plank. Future research should seek to determine whether the increased muscle activation associated with the long-lever posterior-tilt plank transfers to improvements in functional performance and injury prevention.

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