A Review on Postural Realignment and its Muscular and Neural Components

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Posture is the alignment and maintenance of body segments in certain positions, such as standing, lying, or sitting. There is thought to be an optimal posture for any given task (Gracovetsky, 1988). Considerable deviations from optimal posture are thought to be aesthetically unpleasant, adversely influence muscle efficiency, and predispose individuals to musculoskeletal or neurological pathologic conditions (Novak & Mackinnon, 1997; as cited in Hrysomallis & Goodman, 2001).

It has been stated that if body segments are held out of alignment for extended periods of time, the muscles will come to rest in a shortened or lengthened position (Bloomfield, 1994; as cited in Hrysomallis & Goodman, 2001). Over time this may result in adaptive shortening or lengthening (Novak & Mackinnon, 1997; as cited in Hrysomallis & Goodman, 2001). Muscles that undergo adaptive shortening become tight and strong, placing the opposing muscles in a lengthened and weakened position (Kendal, et al., 1993). These changes in resting muscle length may influence postural alignment. It has also been proposed that adaptive muscle shortening may occur as a result of muscle overuse, particularly in shortened ranges of motion (Janda, 1993; Kelly, 1949). This is likewise believed to cause postural deterioration.

Exercise has been promoted as a means to correct postural deviations resulting from the above two causes. It is said that exercise may correct such postural deviations as excessive lumbar lordosis, scoliosis, kyphosis, and abducted scapulae (Reiter & Cato, 1970; Wells, 1963; Zatsiorsky, 1995). This may be a result of improved muscle balance.

Before any discussion can be made on issues pertaining to postural realignment however, two underlying factors must first be addressed. The first of these is an overview of the postural muscles. The muscles that are involved in maintaining posture will depend to some degree on the activity or position of the person, but by and large we can make generalizations on which muscles are the primary postural muscles. The postural muscles for upright posture are commonly thought to be the abdominal muscle group and the back extensors (Kelly, 1949; Hrysomallis & Goodman, 2001). However, this is far too limited a description because the muscles on the sole of the foot, the calf muscle group, anterior thigh muscles, posterior hip muscles and the muscles between the shoulder blades have also been suggested as postural muscles (Kelly, 1949). This has been supported by the work of Hughes and colleagues (2000), which showed that the plantarflexors of the ankle, knee flexors, hip extensors, and shoulder flexors were important postural muscles. Another study also found that the soleus, medial gastrocnemius, and tibialis anterior play a role in posture in general and balance in particular (Bloem, et al., 2002). The plantar flexors and dorsiflexors are again indicated as important postural control muscles in the work of Yaggie and McGregor (2002).

The second underlying factor that must be addressed is optimal posture. While much has been written on the importance of optimal posture (for example Gracovetsky, 1988; Phelps & Kiphuth, 1932) and how to develop it (for example Wells, 1963) little research exists on what are the exact characteristics of optimal posture. Without support from research, Wells (1963, p. 4) suggests the following criteria for optimal standing posture:

1. The total body weight is centered squarely above both feet or else is very slightly forward, but never backward.
2. The major weight-bearing segments of the body are aligned in a single straight line, either vertical or slanting very slightly forward from the ankles.
3. The pelvis is centered squarely above the feet and beneath the trunk, providing firm support for the latter.
4. The chest is slightly lifted but the elevation is not forced.
5. The head is erect with the profile vertical and the chin level.
6. The feet point forward or slightly outward.
7. The ankles, as seen from the front or back, are straight.
8. The total posture is maintained without evidence of strain or tension.

In a more concise description, but also without much scientific support, Reiter and Cato (1970) describe optimal posture as one where equal parts of the torso lie anteriorly and posteriorly to the sagital plane and in which there is little or no curvature of the spine from a posterior view. These recommendations have two major limitations. The first of these limitations is that neither of them is supported by research. The second limitation is that the suggestions are only meant for standing posture. It has been suggested that an optimal posture appears to be task specific (Gracovetsky, 1988), and as such these recommendations might not apply to dynamic posture. Reiter & Cato (1970) did however note that an individual's standing posture might give an indication of their dynamic posture. Gracovetsky (1988) developed a postural model without the limitations of the previous sets of suggestions. This mathematical model can be applied to all forms of posture (sitting, standing, walking, etc.). This model defines optimal posture as one in which total stress is minimized on each joint and the stress on all the muscles is equalized. The components that make up this total joint stress in this model are shear stress, compression, ligament tension, and muscle activity. Equalization of these forces means that the stresses of the system are balanced in such a way that the sum of all the joint stresses is minimized. Regardless, of which of these models or set of suggestions is followed, there seems to be an underlying understanding that most individuals do not typically employ an optimal posture. This may be a result of either muscular or neural issues.

Muscular issues related to postural realignment

When taking the view that posture is solely the result of adaptive shortening, muscle balance is often what is being referred to. Muscle balance is the relationship between the strengths and lengths of opposing muscles. It is commonly thought to be a necessary and important factor in postural control (Kelly, 1949; Phelps, et al.; 1932; Reiter & Cato, 1970; Wells, 1963; Zatsiorsky, 1995). Much like optimal posture, there is no consensus on the concept of muscle balance as to what exactly should be balanced. In any case, it is often assumed that posture will be a result of the relationship between the opposing muscles' strength and length. The assumption is that strengthening a weak and lengthened agonist muscle group will result in adaptive shortening, and, when combined with stretching of the short antagonist, postural realignment will result (see review in Hrysomallis & Goodman, 2001).

Because of its role in adaptive shortening and muscle balance it is widely believed that muscular strength plays a large role in postural maintenance (Bloomfield, 1994; Brandt, Buchele, and Kraczyck, 1986; Holloway, 1994; Kelly, 1949; Kendall et al., 1993; Phelps & Kiphuth, 1932; Reiter & Cato, 1970; Zatsiorsky, 1995). Muscular strength is defined as the maximal force that a muscle or group of muscles can generate (Harman, 1994). It has been indicated that postural problems may be a result of weak muscles. For example, Holloway (1994) suggested that a slumping, round-shouldered posture might be the result of both weaknesses in the upper back and inflexibility of the upper chest and anterior shoulder.

Strength can be classified into several subcategories. Two of these subcategories, static and dynamic strength, may be of particular relevance to postural maintenance and realignment. Static strength is the ability to contract a muscle without movements and dynamic strength is the ability to apply force during movements.

Despite opinions to the contrary, research supporting the importance of either of these subcategories of strength is lacking. In fact, dynamic strength has been shown to have no significant correlation with lumbar lordosis (Walker, et al., 1987). It might however, be expected that static strength would be more important to posture than dynamic strength because postural muscular contractions are typically tonic in nature (Foss & Keteyian, 1998). This hypothesis is also not supported by research. One study found that there was no significant relationship between lumbar lordosis and static strength of the trunk flexors and extensors and hip flexors and extensors (Flint, 1962).

Possibly more important than muscular strength (whether static or dynamic) is muscular endurance since postural muscular contractions must be sustained for long periods of time. Static muscular endurance is the ability of a muscle or muscle group to sustain a contraction for an extended period of time (Foss & Keteyian, 1998). Since posture is maintained by a tonic muscular contraction (Foss & Keteyian, 1998), we might assume that muscular endurance might be more important than muscular strength in maintaining posture. One research study however, has indicated that this may not be the case (Mulhearn & George, 1999). In this study, lumbar posture of 23 elite gymnasts and 28 controls was subjectively assessed. Isometric abdominal endurance was measured and the researchers concluded that there is no significant relationship between abdominal muscle endurance and lumbar posture. Reliability and validity for their tests was not reported.

The other factor in the muscle balance relationship is muscle length. Muscle length is often approximated by measures of joint range of motion. The assumption in the adaptive shortening theory is that muscles of disproportionately short length may limit posture by pulling on body segments. There is little research to support this hypothesis. Coppock (1958) investigated flexibility of the pectoral muscles and its relationship with abducted scapulae in 124 women. The results indicated that the resting distance between the scapulae was not significantly associated with pectoral muscle length. Another study (Flint, 1962) attempted to correlate range of movement of trunk flexion and extension and hip extension of women with lumbar lordosis. Like the previous study, no significant correlation was detected. Another study by Youdas and colleagues (1996) produced similar results. They found that back muscle length was not significantly associated with lumbar lordosis for men or women. This same study performed a multivariate analysis using a combination strength and flexibility variables and it was found that standing lumbar lordosis was only weakly associated with length (not muscle weakness) of abdominals and 1-joint hip flexor muscle length (but not back muscle length).

Neural issues related to posture

The neural effect on posture is largely ignored (see review Hrysomallis & Goodman, 2001). This could be considered a drawback of current intervention studies because postural stability during static and dynamic situations is maintained by both feed-forward control and rapid feedback corrections of the nervous system (Ghez, 1991; Roberts, 1978; Houk, 1979). To say that posture is simply a result of muscle balance would neglect the fact that a muscle's state of tension and length are dependent on signals from the nervous system. Although the previous section reviewed muscular issues related to posture, from a neuromuscular standpoint, the regulation of the skeletal muscles by the central nervous system is organized in terms of the individual motor units rather than in terms of individual muscles (Roberts, 1978).

All muscles, including the postural muscles contain a variety of receptors. Of particular interest to this review is the Golgi tendon organs and muscle spindles. Golgi tendon organs sense changes in tension and muscle spindles sense changes in length and relay this information to all levels of the nervous system. This proprioceptive information shapes reflex responses and is at the root of postural maintenance (Gordon & Ghez, 1991). Reiter & Cato (1970) indicated that the development of proprioception might be the most important factor for postural realignment.

Playing a large part in proprioception is the stretch reflex. The stretch reflex has been demonstrated to be of primary importance to postural control (Bloem et al., 2002). The stretch reflex acts to resist lengthening of the muscle. In so doing, stretch reflexes enhance the spring-like quality of muscles. When a person's posture shifts, the muscles resist being stretched, preventing our movement from becoming too great. In fact, it has been found that subjects who lose their stretch reflex due to neuropathy have poor posture correction abilities as indicated by increased velocity profiles of trunk sway (Bloem, et al., 2002).

Several studies have indicated the importance of distal proprioceptors in the correction and maintenance of balance. One study (Sorensen, et al., 2002) investigated the contribution of ankle muscle proprioception to the control of dynamic stability and lower limb kinematics during adaptive locomotion, by using mechanical vibration to alter the muscle spindle output of individuals' stance limbs. Vibrating the ankle muscles of the stance limb during the step over an obstacle resulted in significant changes to center of mass behavior in both the medial/lateral and anterior/posterior planes. The results provide strong evidence that the muscle spindles of the ankle play a significant role in the control of posture and balance during the swing phase of locomotion by providing information describing the movement of the body's center of mass with respect to the support foot.

Another study also provided support for the importance of the distal proprioceptors (Hughes, et al., 1995). In this study, dynamic postural control was examined by using perturbations to disturb standing balance. Kinematics and electromyography of the reaction to an unexpected slip were examined simultaneously in

16 young, healthy volunteers. Kinematic results showed ankle plantarflexion, knee flexion, hip extension, and shoulder flexion.

Another study (Bloem, et al., 2002) indicated that weaker balance-correcting responses in subjects produced changed trunk velocity profiles (mainly a reduced initial backward motion of the trunk), but lower-body segment movements showed no consistent differences between the two groups. Considering these body segment displacements, the researchers concluded that any automatic postural response with an onset time within the first 200 ms might be triggered by receptors located at the knee, hip or trunk

Numerous studies have examined the neuromuscular strategies and muscular recruitment patterns used to maintain posture. For example, Nashner and colleagues (as cited in Ghez, 1991) found that postural responses to perturbations occur through the contraction of muscles in a highly characteristic distal-to-proximal sequence: the first muscles to contract were those that are closest to the base of support. Research conducted by Hughes and colleagues (1995) produced similar results. Another study investigated the influence of trunk posture on musculoskeletal stability of the spine (Granata, & Wilson, 2001). It was concluded that muscle recruitment patterns are more accurately explained by stability than by equilibrium alone.

Patients with low back pain have been particularly useful in the study of recruitment patterns. One study indicated that the mechanism of preparatory spinal control might be altered in people with lower back pain for movement at a variety of speeds (Hodges & Richardson, 1999). Researchers found that early activation of Transversus abdominis and Obliquus internus abdominis occurred in the majority of trials, with movement at both the fast and intermediate speeds for the control group. In contrast, subjects with low back pain failed to recruit Transversus abdominis or Obliquus internus in advance of limb movement with fast movement, and no activity of the abdominal muscles was recorded in the majority of intermediate speed trials. There was no difference between groups for slow movement. The results indicate that the mechanism of preparatory spinal control is altered in people with lower back pain for movement at a variety of speeds.

In another study using people with low-back pain, Hodges (2001) also found changes in trunk muscle recruitment have been identified in people with low-back pain. Subjects were tested to see whether the differences in recruitment patterns of people with low-back pain might be due to changes in the planning of the motor response or due to delayed transmission of the descending motor command in the nervous system. These two possibilities were investigated by comparison of the effect of task complexity on the feed-forward postural response of the trunk muscles associated with rapid arm movement in people with and without lower back pain. The onsets of electromyographic activity of the abdominal and deltoid muscles were measured. The results indicated that it is likely that the change in recruitment of Transversus abdominus represents a more complex change in organization of the postural response rather than delayed transmission of the descending motor command in the nervous system.

While the focus of the neural section of this review has been on the muscle receptors needed for postural maintenance and correction, there are several other important neurological structures that might play a role in postural maintenance and correction. The basal ganglia may be one such a structure. Parkinson’s disease patients have damage to the basal ganglia (Leonard, 1998). A study on Parkinson's disease patients demonstrated major problems with postural instability (Van Wegen, et al. 2001). This study demonstrated that patients with Parkinson's disease show clear changes in postural and balance control strategies from non-Parkinson's disease patients; indicating the importance of the basal ganglia in postural correction.

The vestibular system also plays a role in posture. The vestibular system is a complex sensory system that is linked with balance, head control, and eye-tracking tasks (Leonard, 1998). The semicircular canals, utricle, and saccule comprise the peripheral receptors of the vestibular system. The vestibular nuclei receive input from the peripheral labyrinth receptors, the reticular formation, and the cerebellum. The output from the vestibular nuclei is primarily to motor neurons within the spinal cord, specifically, to motor neurons innervating proximal muscles and muscle spindles of the neck and back.

Postural realignment

Obviously, any attempts at postural realignment must take into account the role of both the muscular and neural components related to posture. Most of the current proposed interventions focus on exercise. Exercise has been promoted as a way to correct such postural deviations as excessive lumbar lordosis, scoliosis, kyphosis, and abducted scapulae (Reiter & Cato, 1970; Wells, 1963; Zatsiorsky, 1995). In using exercise as a form of intervention, it is assumed that the cause of the problems is muscle imbalance. This however may not fully take into account the neural component of posture. Research examining postural realignment has produced mixed results.

There is a notion that certain activities or sports may predispose the participants to changes in posture. Perhaps the best support for the effectiveness of postural realignment through exercise may come from studies on sports participants. In one such a study (Watson, 1983), 181 men aged 17-20 years participants were classified according to their primary sport. Ninety-eight were classified as soccer, Gaelic football, or rugby players, the remaining 83 participants were classified as "other sportsmen" (track athletes, gymnasts, volleyballers, basketballers, swimmers, and racket sport players). Posture was rated by comparing the subjects to a series of 5 drawings and rating each subject with a score of 1 (bad posture) to 5 (ideal posture) for each of the following conditions: kyphosis, lordosis, scoliosis, and rounded shoulders. Reliability trials conducted with 20 subjects found that 99% of the scores were within 1 unit and 69% of the scores were within 0.5 points. It was found that there was a significantly higher incidence of lordosis in the soccer and football players when compared to the other sportsmen. It was proposed that tightness of the quadriceps from strengthening associated with kicking might have influenced pelvic tilt and lordosis. The validity of this experimental method was never reported. In the second part of this study, subjects participating in Gaelic football and soccer were monitored over a period of 21 months. It was found that subjects participating in these two sports showed a significant increase in lordosis. This indicates that activity participation and posture may be linked. Again, reliability and validity were not reported.

Another study examined steeplejacks, tight-rope artists, and gymnasts and noted that their postural reflexes were significantly higher than average (Brandt, et al., 1986). The results indicated that congenital postural reflexes may not be optimized under daily life conditions but can be adjusted to higher performance by training.

Despite the findings of these studies, the results of actual intervention studies are mixed. One study tested the hypothesis that by increasing back extensor strength with exercise, kyphotic deformities would be reduced or their progression minimized (Itoi et al., 1994; cited in Hrysomallis & Goodman, 2001). Subjects were healthy, estrogen-deficient women between the age of 49 and 65 years. Maximum isometric prone back extension was determined with a dynamometer. The prone back extension exercise did not increase lumbar lordosis as would be argued with stronger and "tighter" lower erector spinae muscles.

Another study produced results in support of the effectiveness of realignment exercises (Richardson, et al., 2001). This study tested to determine the effect of a specific exercise regimen on clinical measures of postural stability and confidence in a population with peripheral neuropathy. A 3-week intervention exercise regimen was designed and implemented to increase rapidly available distal strength and balance. It was concluded that a relatively short and specific exercise program can improve clinical measures of balance in patients with diabetic peripheral neuropathy.

In another study, patients with Parkinson's disease were put on a bi-weekly resistance-training program for an 8-week period (Scandalis, et al., 2001). The exercises in the training program focused primarily on the legs. It was found that the training program resulted in significant gains in stride length, walking velocity, and postural angles when compared with pretreatment values.

Perhaps the reason for the mixed results of the previous studies is due to the fact that the research focused on strengthening the lengthened agonist muscle without concurrently stretching the "tight" antagonist muscle. This may be the source of the mixed findings because if we assume that the muscle balance theory is actually true, than strengthening agonist muscles without concurrently stretching antagonist muscles may be of little use. In fact, it has been reported that strengthening on its own may not be effective in postural correction unless the agonist is also stretched (Norris, 1993 as cited in Hrysomallis & Goodman, 2001). One study examining the effect of a combination of stretching and strengthening exercises has shown that such a program may be effective in decreasing lumbar lordosis (Alizadeh & Standring, 1996). Lumbar lordosis, hip flexor range of motion, and lumbar flexion range of motion were measured prior to the start of the exercise program. Nine men with a larger degree of lumbar lordosis were selected to be in the exercise group. The control group consisted of nine men with 'average' lumbar lordosis. The exercise group performed both flexibility and stretching exercises to improve muscle balance. The results showed that the exercise group significantly decreased lumbar lordosis.

Regardless of the mixed findings of the previously mentioned studies, a common link between all of them is that they seem to ignore the neural component of postural maintenance and correction. Postural corrective programs might benefit from an increased focus on propriocptive awareness. It may help to 're-educate the muscles' so that individuals become more aware of inappropriate muscle activity. In this way, individuals can learn to correct themselves and in so doing establish certain postures and movement patterns.

Another possibly limitation of all of these studies is the time duration of the exercise programs. The mixed results of the studies examined may be a result of the varying frequency and duration of the exercise programs. Short duration exercise programs may be insufficient to elicit any adaptive shortening of muscles. Even if individuals could exercise long enough in a restricted range of motion, any potential length adaptations would most likely be offset by daily living activities that often require full range of motion.

Conclusion

Posture is a multi-faceted topic that is still not yet fully understood. Based on the findings of the research presented, the possibility of postural realignment is debatable and the effectiveness of corrective programs is questionable. There is some evidence from sports participants to suggest that changes in posture may occur as a result of certain activities but research results on the effectiveness of postural correction are mixed. There is also some evidence to suggest that resistance training for the antagonist will cause adaptive shortening; and when combined with flexibility exercises may result in changes in static posture. Future research should address the limitations identified in these studies. Further research on the role of the muscular and neural systems will also be of use. Understanding the interplay of the muscular and neural aspects of postural control will give insight into posture in general and perhaps provide knowledge necessary to develop an effective corrective program.

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