CHAPTER 4

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Dynamic Neuromuscular Stabilization: Exercises Based on Developmental Kinesiology Models

INTRODUCTION

The etiology of musculoskeletal pain, in particular back pain, is often evaluated from an anatomical and biomechanical standpoint and the influence of external forces (i.e., loading) acting on the spine. However, the evaluation of the forces induced by the patient's own musculature, is often missing. The stabilizing function of muscles plays a critical and decisive postural role and depends on the quality of central nervous system (CNS) control. Kolar's approach to dynamic neuromuscular stabilization (DNS) is a new and unique approach explaining the importance of neurophysiological principles of the movement system. The DNS encompasses principles of developmental kinesiology during the first year of the life; these principles define ideal posture, breathing patterns, and functional joint centration from a "neurodevelopmental" paradigm (1). DNS presents a critical set of functional tests assessing the quality of functional stability of the spinal and joint stabilizers and assisting in finding the "key link" of dysfunction. The treatment approach is based on ontogenetic global postural-locomotor patterns (2,3). The primary goal of treatment is to optimize distribution of internal forces of the muscles acting on each segment of the spine and/or any other joint. In the DNS treatment concept, patient education and participation are imperative to reinforce ideal coordination among all stabilizing muscles.

POSTURAL ONTOGENESIS AND MATURATION OF THE INTEGRATED STABILIZING SYSTEM OF THE SPINE, CHEST, AND PELVIS

Postural ontogenesis entails maturation of body posture and related human locomotion (1–3). Postural muscle function ensures all possible positions in the joints determined by their anatomical shapes and has a strong formative influence on bone and joint morphology. Postural muscle activity is genetically predetermined and occurs automatically during CNS maturation. During newborn stage (Figures 4.1 and 4.2), bones and joints are morphologically immature. For example, the shape of the plantar arch is not well defined (4,5), the chest is shaped like a barrel, the posterior angles of the lower ribs are situated anteriorly relative to the spine, the ribs appear to be more horizontal than in adulthood (6), and the spine is maintained in kyphosis as the spinal lordotic curves have not yet developed (7–9). As the CNS matures, purposeful muscle function increasingly occurs. Muscles controlled by the CNS subsequently act on growth plates influencing the shape of bones and joints. Every joint position depends on stabilizing muscle function and coordination of local and distant muscles to ensure "functional centration" of joints in all possible positions. The quality of this coordination is crucial for joint function and influences not only local but also regional and global anatomical and biomechanical parameters starting in the early postnatal stage.

Ontogenesis demonstrates a very close relationship between neurophysiological and biomechanical principles, which are important aspects in the diagnosis and treatment of locomotor system disorders. This relationship is very apparent in cases where there is a CNS lesion and muscle coordination is affected. The disturbed muscle coordination subsequently alters joint position, morphological development, and ultimately posture (Figure 4.3) (10,11). Postural function and motor patterns are not only the indicators of the stage of maturation, but can point to the fact if the CNS development is physiological or pathological (1–3,12,13). Posture is a term very closely related to early individual development. The quality of verticalization during the first year of life strongly influences the quality of body posture for the rest of a person's life. During early postural ontogenesis, lordotic and kyphotic spinal curves as well as chest and pelvic positions are established. This process corresponds to stabilization of the spine, pelvis, and chest in the sagittal plane at the age of 4.5 months (Figures 4.4 and 4.5). This is followed by the development of phasic locomotor

FIGURE 4-1. Typical supine posture of a newborn. Asymmetrical head and body position, showing head predilection (i.e., newborn's preferred head rotation toward one side). Postural immaturity is related to morphological (anatomical) immaturity; underdeveloped chest is short and shaped like a barrel, ventrodorsal chest diameter is larger than the width of the chest, and the posterior angles of the lower ribs are situated anteriorly relative to the spine.

FIGURE 4-2. Typical newborn prone posture, with asymmetrical head predilection position as in supine position. There is no equilibrium as weight-bearing zones have not been defined yet, and the infant cannot hold any segment against gravity. The entire spine is maintained in kyphosis with an anterior pelvic tilt.

function of the extremities, which includes the stepping forward (or reaching, grasping) function and the supporting (or taking off) function (1–3,12). These locomotor function of the extremities develops in two patterns. In the ipsilateral pattern, the leg and arm on the same side serve as a support function (and/or taking off), whereas the other same-sided leg and arm fulfill the phasic, that is, stepping forward and grasping, function (Figure 4.6). Ipsilateral pattern develops from supine position and is later integrated in the process of turning, oblique sitting, and other patterns. On the other hand, in the contralateral pattern, for example, if the right arm functions as a support, then the left leg will also function as a support function at the same time. The left arm has a grasping function and the right leg has a stepping forward function (Figure 4.7). Contralateral pattern develops from prone position and is later integrated in creeping, crawling, or

FIGURE 4-3. Postural effects from cerebral palsy (spastic diparesis). Note structural deformities of the hips, knees, and feet as a result of compromised muscle function due to central nervous system lesion.

FIGURE 4-4. A 4.5-month physiological infant in supine position. Chest, pelvis, and spinal stabilization in the sagittal plane is fully established and maintained by proportional coactivation between agonists and antagonists (see Figure 4.12 for details). Supine weight-bearing zones include the nuchal line, shoulder blades, sacrum, and upper sections of the gluteal muscles. The infant is able to lift the pelvis above the table as far as the thoracolumbar junction due to established spinal stabilization in the sagittal plane.

FIGURE 4-5. A 4.5-month physiological infant in prone position. Weight-bearing zones include the medial epicondyles, bilateral anterior superior iliac spine and pubic symphysis. This posture allows the infant to hold the segment (e.g., head or legs) out of the base of support against gravity. When lifting the head, the spine uprights starting at the mid-thoracic segments. Upper thoracic segments functionally belong to the cervical spine.

gait movement patterns. The ipsilateral and contralateral locomotor patterns of the extremities begin to develop simultaneously after stabilization in the sagittal plane is fully completed, which physiologically corresponds to the age of 4.5 months.

The stepping forward function corresponds to open kinetic chain activities, where the direction of muscle pull is proximal and typically involves movement of the head of the femur or the humerus on a stable acetabulum or glenoid fossa, respectively. The principles are reversed on

FIGURE 4-6. Ipsilateral movement pattern and function of extremities. Right-sided extremities serve for support and weight bearing while the left arm reaches forward (as in grasping function) and left leg swings forward (as in stepping forward function). Note the "reciprocal" position of the opposite extremities, for example, the right (supporting) foot is in plantar flexion and inversion while the left (stepping forward) foot is in dorsiflexion and eversion. The right arm moves toward pronation, while the left arm moves toward supination.

FIGURE 4-7. Contralateral movement pattern and function of the extremities. The left leg (medial condyle of the knee) provides support while the left arm reaches forward (grasping); the right leg steps forward and the right arm provides support (medial epicondyle of the elbow). Note the reciprocal position of the feet again—the left supporting foot is in plantar flexion and inversion, and the right stepping forward foot is in dorsiflexion and eversion.

the supporting side, where the extremity works in a closed kinetic chain. The direction of muscle activity is distal (toward support, i.e., weight-bearing area) and typically involves the movement of the fossa over the stabilized head of the humerus or femur (Figures 4.8 and 4.9).

All afferent systems, including vision (14–16), hearing (17), vestibular (18,19), proprioceptive, and exteroceptive information (20), are integrated in these global patterns of stabilization and stepping forward/supporting extremities' function. In addition, the orofacial system takes part in these complex movement patterns (2,3,12,21). For example, during a throwing action, the athlete automatically places the extremities in a reciprocal position, the eyes and tongue turn toward the same direction as the stepping forward (throwing) arm (eyes preceding the arm movement), enhancing further facilitation and performance of the throwing movement. The athlete shown in Figure 4.10 depicts how all his orofacial muscles are involved in movement, to enhance maximum strength and performance. If the athlete is asked to look in the opposite direction or turn his tongue against the direction of the stepping forward arm movement, it will significantly decrease his sports performance. These principles can be powerfully used in athletic training.

Activation of the stabilizers is automatic and subconscious (the "feed-forward mechanism") and precedes every purposeful movement (Figure 4.11) (22). Any purposeful movement influences global posture and this posture subsequently influences the quality of phasic (dynamic) movement. The integrated stabilizing system of the spine consists of well-balanced activity between deep neck flexors and spinal extensors in the cervical and upper thoracic region. Stability of the lower thoracic and lumbar region depends

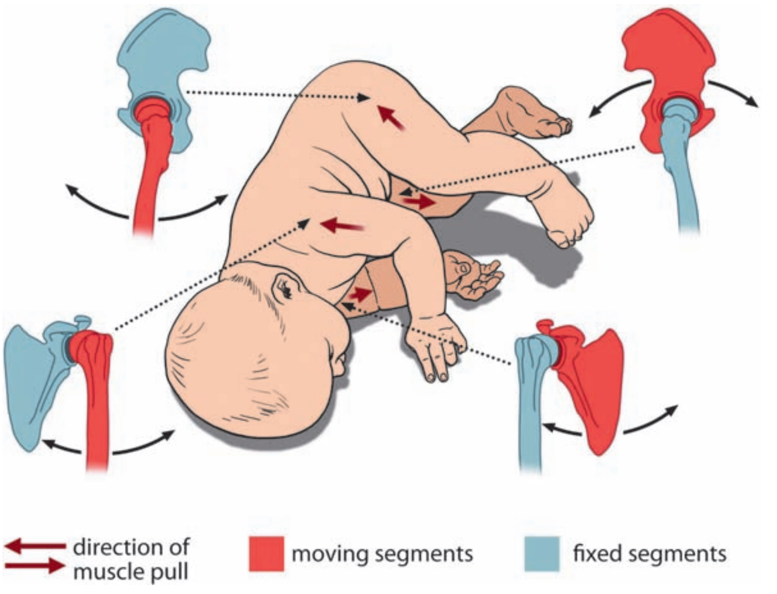

FIGURE 4-8. In an ipsilateral pattern in this case, the left-sided extremities have a stepping forward function. The direction of muscle activity is proximal; the glenoid fossa and acetabulum are relatively fixed and serve as a stable base, while the head of humerus and femur rotates around the stabilized cavity. In other words, the distal segments (extremities) move against a fixed proximal stable base (scapula, pelvis). The opposite is true for the supporting or weight-bearing right arm and leg. The direction of muscle pull is distal; the humerus and femur are now relatively fixed while the glenoid fossa and acetabulum move around them. In other words, the proximal scapula and pelvis move against relatively fixed distal extremities.

on the proportional activity between the diaphragm, pelvic floor, and all sections of the abdominal wall and spinal extensors. The diaphragm, pelvic floor, and abdominal wall regulate intra-abdominal pressure, which provides anterior lumbopelvic postural stability (Figure 4.12) (23–28). In the newborn stage, the diaphragm functions only as a respiratory muscle. Between 4 and 6 weeks of age, the first postural activity occurs; the infant starts to lift his/her head (when prone) and legs (when supine) against gravity and the diaphragm starts to fulfill its dual function as a respiratory and postural muscle. The dual function of the diaphragm is essential for all movements and even more importantly during all types of sports performance (29,30). Under pathological conditions, insufficient postural function of the diaphragm, abnormal recruitment and timing between the diaphragm and abdominal muscle activity (31), atypical initial chest position (due to imbalanced activity between the upper and lower chest stabilizers, with upper stabilizers dominating), and hyperactivity of the superficial spinal extensors can be observed.

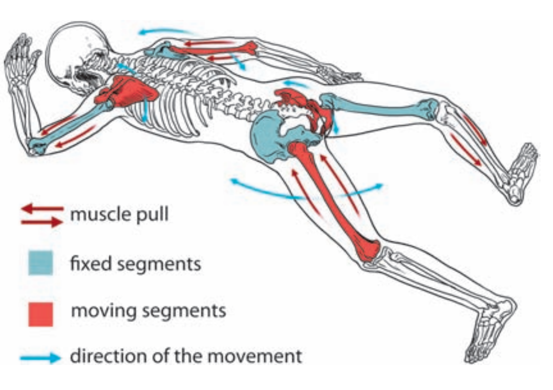

FIGURE 4-9. In a contralateral pattern in this case, the left arm and right leg have a supporting function, and the right arm and left leg have a stepping forward function.

DNS diagnosis is based on comparing the patient's stabilizing pattern to the developmental stabilization pattern of a healthy infant. For example, we compare the patient's supine posture when holding the legs above the table (Figure 4.13) and prone (Figure 4.14) sagittal stabilization during trunk extension test with that of the physiological pattern of a 4.5-month-old baby. The DNS therapeutic system makes use of specific functional exercises to improve spinal and joint stability by focusing on the integrated spinal stabilizing system. However, the primary target is the brain, which must be properly stimulated and conditioned to automatically activate optimal movement patterns necessary for coactivation of the stabilizers. The ultimate strategy is to "train the brain" to maintain central control, joint stability, and ideal quality of the movement restored during therapeutic intervention. This is achieved by activation/stimulation of the stabilizers when placing the patient in primal developmental positions (see the section "Sample Exercises"). As the program advances and becomes more challenging, these ideal movement patterns fall under the patient's voluntary (cortical) control, requiring less assistance from the clinician. Eventually, through repetition of the exercises, the central control establishes an automatic model that becomes a fundamental part of everyday movement. Integration of the ideal pattern of stabilization in sports activities not only decreases the risk of injuries and secondary pain syndromes resulting from overloading but also improves sports performance.

FIGURE 4-10. Reciprocal function of extremities in a javelin thrower. Note the integration of the orofacial system in the global posture. Eyes and tongue turn toward the same direction as the throwing arm, preceding the throwing action.

MOTOR DYSFUNCTION (ABNORMAL MOTOR PATTERNS) AS AN ETIOLOGICAL FACTOR IN INJURIES AND/OR PAIN SYNDROMES

The anatomy of a muscle is considered to be the decisive factor for muscle strengthening. Specific types of exercise designed for individual muscles are based on the knowledge of the muscle's attachments. Most of fitness machines and benches are based on muscle anatomy. When strengthening muscles, or when analyzing muscle weakness or the muscle's influence on joints, bones, and soft tissues, anatomy and neurobiomechanics of muscles as well as muscle integration into biomechanical chains must be taken into account. CNS control and its associated programs play a critical role in proper integration of these muscle chains (32–34). Under both, static (sitting or lying) and dynamic (locomotion) conditions, individual movement segments must be stabilized by coordinated activity between agonists and antagonists. In other words, a coactivation synergy is necessary and must be trained. Another critical aspect is to train both directions of muscle pull, that is, to train the muscle in both stepping forward (open kinetic chain) and supporting (closed kinetic chain) functions. The most frequent mistake in strength training is that only one direction of muscle activity is trained, for example, the pectoralis is strengthened in open kinetic chain all the time (Figure 4.15), but not in closed chain (Figure 4.16). In brief, it is imperative to train muscles in both, open and closed kinetic chains.

This stabilizing or postural function always precedes any phasic (purposeful) movement (22). Pathology or dysfunction frequently occurs when the muscle is strong enough in its phasic function (or anatomic function) but lacks in its postural (stabilizing) function, thus resulting in postural instability. Poor pattern of stabilization is easily fixed in the CNS, since stabilization is an automatic and subconscious function. Abnormal stabilization is then integrated into any movement and, especially, sports activities (which require strength, speed, and repetition), compromising the quality of movement stereotypes and resulting in overloading, decreased sports performance, and increased risk of injuries. Stereotypical repeated overloading due to poor pattern of stabilization is a frequent primary cause of movement disturbances and pain syndromes. "Practice does not make perfect, it makes permanent," which is true for both, physiological and pathological patterns. Poor methodology of training (or rehabilitation, for that matter) will fix and reinforce poor stereotypes (Figure 4.17).

Postural instability cannot be evaluated merely by manual muscle testing. Functional postural tests must be used. Kolar's approach to DNS explains and demonstrates the importance of the relationship and proper recruitment of all muscular interactions for dynamic stability of the spine and joints and utilizes a series of systematic dynamic tests. The section on sample tests illustrates the most important tests.

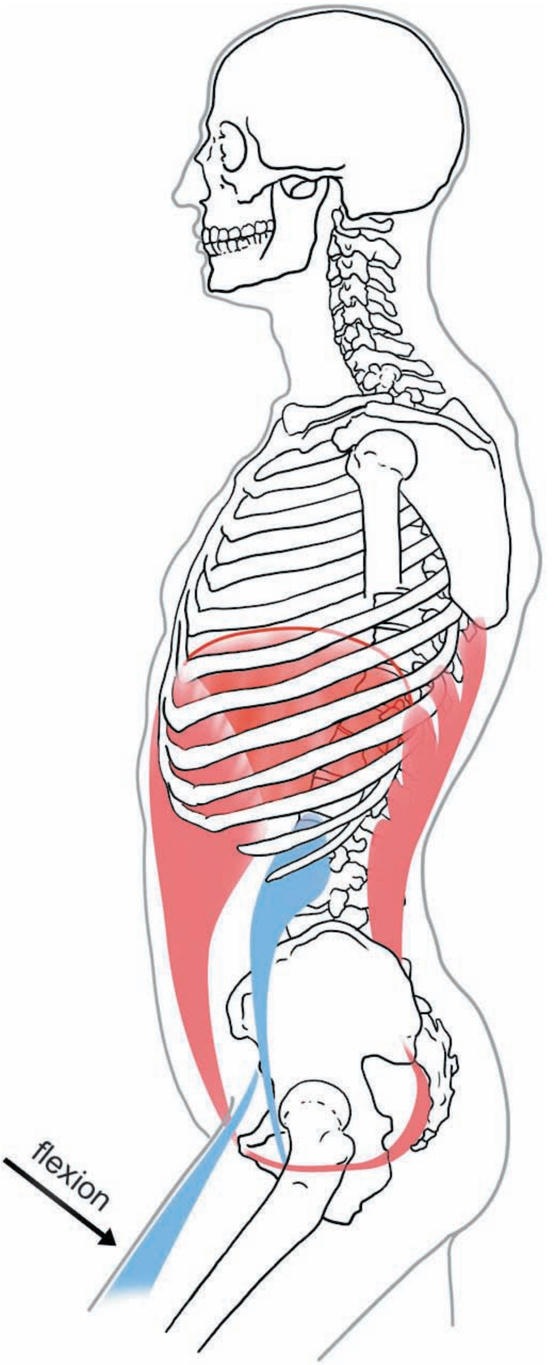

FIGURE 4-11. "Feed-forward stabilization mechanism." Prior to any phasic or dynamic movement (e.g., hip flexion), the stabilizers must be activated, that is, the integrated function of the trunk-stabilizing muscles (dark areas—diaphragm, pelvic floor, all parts of the abdominal wall, and spinal extensors) precedes the activation of hip flexors (light areas) for dynamic hip flexion.

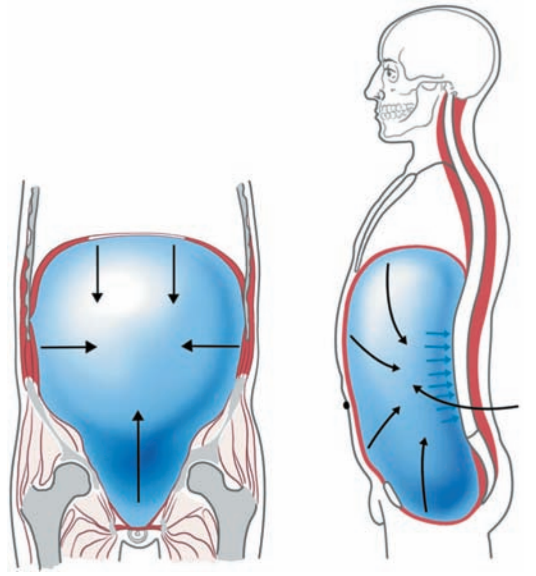

FIGURE 4-12. In a scheme of stabilization, the cervical and upper thoracic region is stabilized by well-balanced activity between deep neck flexors and spinal extensors. The lower thoracic and lumbar segments are dependent on intra-abdominal pressure regulation providing anterior lumbopelvic postural stability, whereas posterior stabilization is ensured primarily by intrinsic spinal extensors.

BASIC PRINCIPLES FOR EXERCISES

Ideal Initial Posture as a Prerequisite for All Exercises

The quality and efficiency of any movement depends on multiple factors. One of the key factors is the initial body position when performing the exercise. Proper stabilization is critical for all dynamic activities ranging from simple functional tasks to skilled athletic maneuvers (35). In the DNS approach, the initial body position is closely related to the pattern of sagittal stabilization. Ideal posture from a developmental perspective is demonstrated in a physiological baby at 4.5 months of age when sagittal stabilization is completed (see Figures 4.4 and 4.5). Ideal muscle coordination is maximized in this position to provide the best possible biomechanical advantage for movement and muscle performance (strength and power). This initial position can also significantly influence movement execution (sports technique) and hence training and sports performance.

Basic Dynamic Neuromuscular Stabilization Tests for Stabilization

Supine

Place the patient in a supine position with hips and knees flexed 90° above the table. Ask the patient to maintain

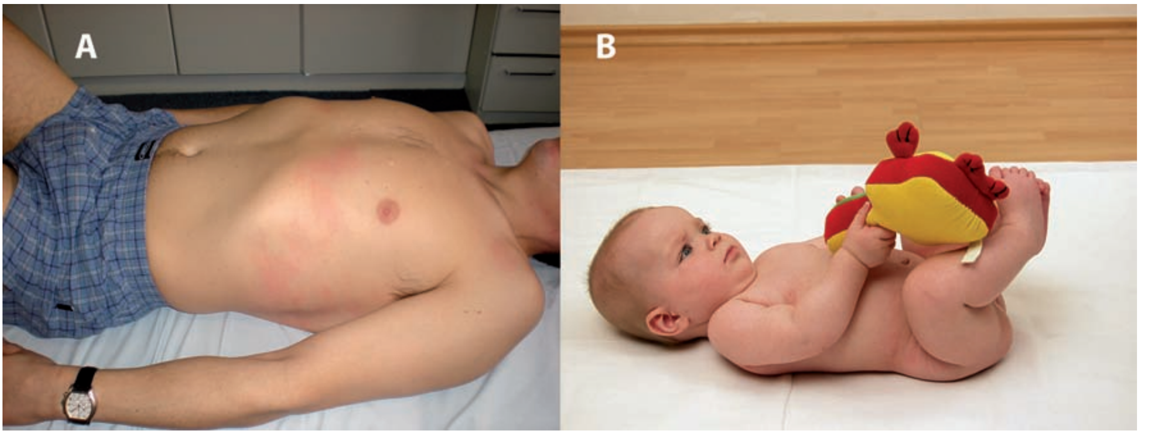

FIGURE 4-13. A comparison of the patient's abnormal supine stabilization pattern (A) with that of a healthy 4.5-month-old infant (B). Compare the following: (1) Head position and activation of neck muscles: The baby's head is supported on a nuchal line with activation of the deep neck flexors. The patient's neck is extended with excessive activation of superficial muscles (sternocleidomastoid, scalenes). (2) Chest position. Note the difference in shape. The infant's chest is in a caudal, neutral position with lower ribs well stabilized. The patient's chest is in more cranial "inspiratory position" with lower ribs flaring out. (3) Back—the infant's entire back adheres to the table (due to sufficient intra-abdominal pressure regulation). The patient's back is extended at the thoracolumbar junction. (4) Abdominal wall—the infant demonstrates proportional activation and contour. The patient demonstrates bulging at the laterodorsal sections of the abdominal wall.

this posture as you gradually remove the support of the legs, while observing the patient's pattern of stabilization (Figure 4.18A). Compare this posture with the physiological 4.5-month old baby posture (Figure 4.18B). Things to look for include the following:

Head: It is in a neutral position, where the nuchal line is the natural weight-bearing zone. If the upper occiput serves as the supporting area, it is often correlated with hyperextension at the cervicocranial junction with hyperactivity of short neck extensors (Figure 4.18C).

Neck: Activity of superficial neck muscles is unnecessary for this posture. Superficial muscles (sternocleidomastoid [SCM], scalenes, upper trapezius, pectoralis muscles) should be relaxed.

Shoulders: These are relaxed and should not be elevated or protracted. Elevation of the shoulders is often related to hyperactive upper chest stabilizers (SCM, scalenes, upper trapezius, pectoralis muscles) (see Figure 4.18C).

Chest: In neutral position, there should be well-balanced activity between upper (SCM, scalenes, upper trapezius, pectoralis muscles) and lower chest stabilizers (oblique abdominal muscle chains, diaphragm, transverse and rectus abdominis). The most common pathology observed is the chest in

FIGURE 4-14. Comparison of the patient's prone stabilization with that of a healthy prone 4.5-month-old infant (B). (A) Trunk extension test—hyperactivity of scapular external rotators (curved arrows, superficial paraspinal muscles at thoracolumbar junction (thick horizontal arrows) and lumbosacral area). Erector spinae is hyperactive to compensate for insufficient deep spinal stabilizers. Anterior pelvic tilt (thick oblique arrows pointing medially) and bulging of laterodorsal sections of the abdominal wall (thin arrows) are signs of inadequate and/or weak postural function. (C) Retraction of the shoulder blades, hyperextension of cervicothoracic junction, and anterior pelvic tilt. Patient's weight-bearing area is at the level of umbilicus; when compared to the infant's supporting areas, weight bearing is at the level of symphysis. The infant's pelvis is in a neutral position compared to the anterior tilt in the patient.

FIGURE 4-15. "Classic" strengthening of pectoral muscles in open kinetic chain. Note the poor pattern of basic stabilization with flaring of the lower ribs and hollowing of the abdominal wall.

FIGURE 4-16. Strengthening in a reciprocal pattern. Left pectoralis is activated in an open kinetic chain (against resistance) while the right one is trained in a closed kinetic chain; the athlete pronates his right forearm against the therapist's resistance while shifting the weight-bearing zone from deltoid toward the elbow. The body (glenoid fossa) rotates on the fixed humerus. The trunk is lifted against gravity and against the therapist's resistance and rotates toward the right supporting arm. The therapist's left hand helps keep the chest in neutral position and resist the trunk movement at the same time.

FIGURE 4-17. Poor pattern of sagittal stabilization with scapular retraction and forward drawn position of the head. This exercise on an unstable surface is very challenging and with an added load, the pathological pattern will only be reinforced.

a cranial position (inspiratory position) due to dominant and hypertonic upper stabilizers (see Figure 4.18C). Palpate the lower and lateral walls of the chest and try to spring the chest (Figure 4.19). The chest wall should be flexible. If the chest is rigid, soft tissue release may be indicated as a precursor to further training. The posterior angles of the lower ribs should contact the table as they are positioned posterior relative to the spine (see Figure 4.18A,B). However, when these angles are in a less than ideal position, arching of the back (see Figure 4.18C) and flaring of the lower ribs are often observed.

Abdominal wall (test of proportional activation among all sections): Palpate the posterolateral sections (often insufficient), upper part of the rectus abdominis (often hyperactive), and the abdominal wall above the groin (frequently insufficient). Diastasis is a sign of abnormal sagittal stabilization.

FIGURE 4-18. Supine test with legs above table (90°/90° position = right angle at hips and knees). (A) Physiological pattern in an adult. (B) Ideal model in a 4.5-month healthy infant. (C) Pathological pattern in an adult, with head reclination, neck hyperextension (support on the occiput instead of the nuchal line), sternocleidomastoid hyperactivity, shoulder protraction, "inspiratory" chest position, arching of the lumbar spine due to reduced weight bearing at the thoracolumbar junction, diastasis recti, and anterior pelvic tilt. Stabilization is insufficient.

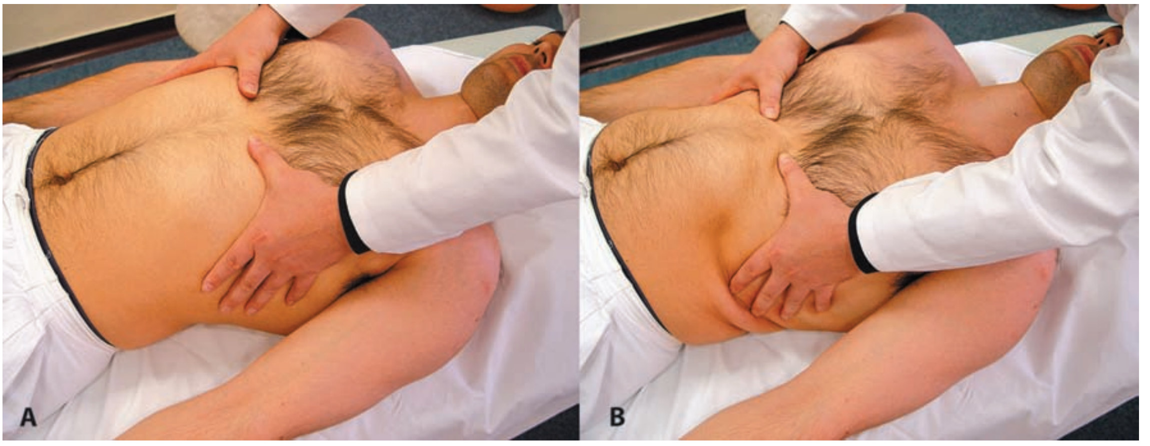

FIGURE 4-19. (A) "Inspiratory" position of the chest is often fixed and it is difficult to bring the chest to neutral position even passively. (B) Bring the chest to neutral position if possible (pull the chest caudally, do not press it against the table!) and spring the chest. The chest should be flexible and spring back symmetrically. Healthy individuals are able to keep the chest in this position at rest, while still breathing, and during the course of all postural activities.

Thoracolumbar (T/L) junction: This serves as a weight-bearing zone and should be in contact with the table (compare Figure 4.18A–C).

Prone

Place the patient in prone position that corresponds to that of a 4.5-month-old healthy infant (Figure 4.20). Ask the patient to lift the head slightly. Observe the following:

Head: In neutral position, it is elevated a few centimeters above the table.

Neck: When lifting the head, extension should start from the mid-thoracic (T3/4/5) segments. Head reclination (hyperextension of cervicocranial junction) and/or hyperextension of the mid- or lower cervical segments as the CT junction is often fixed or flexed is a sign of abnormal extension stereotype. This poor movement pattern is often related to insufficient coactivation of the deep neck flexors (see Figure 4.20C and Figure 4.23A). Compare the posture to that of a healthy 4.5-month-old infant (see Figure 4.20B); note the perfect and gradual lengthening of the entire spine including the cervical spine.

Arms: Medial epicondyles serve as weight-bearing zones. The shoulders should be relaxed, and the patient should not raise them.

Shoulder blades: These should be fixed in a "caudal" position due to balance between the upper and lower scapular stabilizers and between scapular adductors and abductors, with the scapula adhering to the rib cage (see Figure 4.20A,B). An elevated scapula suggests the dominance of the upper stabilizers (see Figure 4.20C). Another common abnormality is winging of the lower angle of the scapula. Proper scapular stabilization is dependent on proper support of the medial epicondyles.

Thoracic spine: Observe the lengthening of the spine. Palpate the mid-thoracic spine during head elevation (Figure 4.21). Normally, you should feel segmental movement between T3/4/5/6.

FIGURE 4-20. Prone test. (A) Physiological pattern in adult. (B) Ideal model in a 4-month-old healthy infant. (C) Pathological pattern in an adult: neck hyperextension, cervicothoracic junction kyphosis, scapular retraction and external rotation, support at the level of the umbilicus instead of the anterior superior iliac spine or symphysis, and pelvic anteversion.

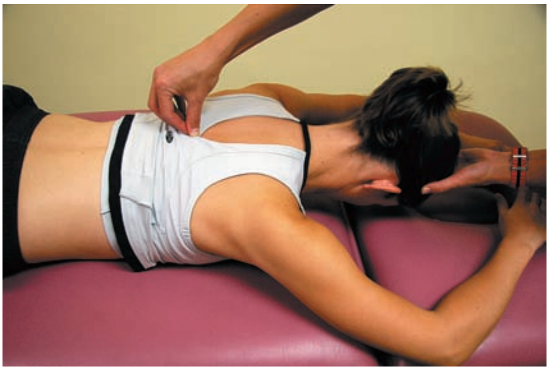

FIGURE 4-21. Palpation of mid-thoracic segments during neck extension test. Neck extension movement pattern should "start" from mid-thoracic spine.

Abdominal wall (proportional activity of all its sections): Palpate the laterodorsal portion; there should be slight activation under your fingers (Figure 4.22). Bulging of the lateral walls is a sign of insufficient sagittal stabilization.

Pelvis (stabilized in a neutral position): Both, anterior and posterior tilts are abnormal. Ask the patient to extend the trunk and palpate the sacrum (Figure 4.23A). The sacrum must be stabilized and remain fixed during the movement. If it tilts ventrally, regulation of the intra-abdominal and intrapelvic pressure is often impaired (see Figure 4.23B). The pubic symphysis and the anterior superior iliac spine (ASIS) are naturally weight-bearing zones (see Figure 4.20A,B).

Legs: Observe and/or palpate hamstrings and triceps surae during neck and slight trunk extension. During the initial phase of trunk extension, these muscles should be fairly relaxed.

FIGURE 4-22. Neck and trunk extension test, with palpation of laterodorsal sections of the abdominal wall. Symmetrical activation should occur during this movement. Superficial extensors at the thoracolumbar junction will often substitute for insufficient activation of the laterodorsal abdominal muscles (see Figure 4.14A).

Standing

Minimal muscle activity is necessary for normal standing posture. Any excessive isometric activity (especially in superficial muscles) is a sign of abnormal posture, which is energy inefficient and may cause overloading of joint segments. Watch (palpate) for muscle tone distribution during primary stance.

The chest must be aligned above the pelvis and the axis of the diaphragm (connecting pars sternalis and costophrenic angle) in the sagittal plane (should be almost horizontal and parallel with the pelvic floor axis) (Figures 4.24A and 4.25B). In this ideal position, the diaphragm may then work against the pelvic floor, especially during any physical strain, in coordination with the abdominal wall, exerting pressure on the

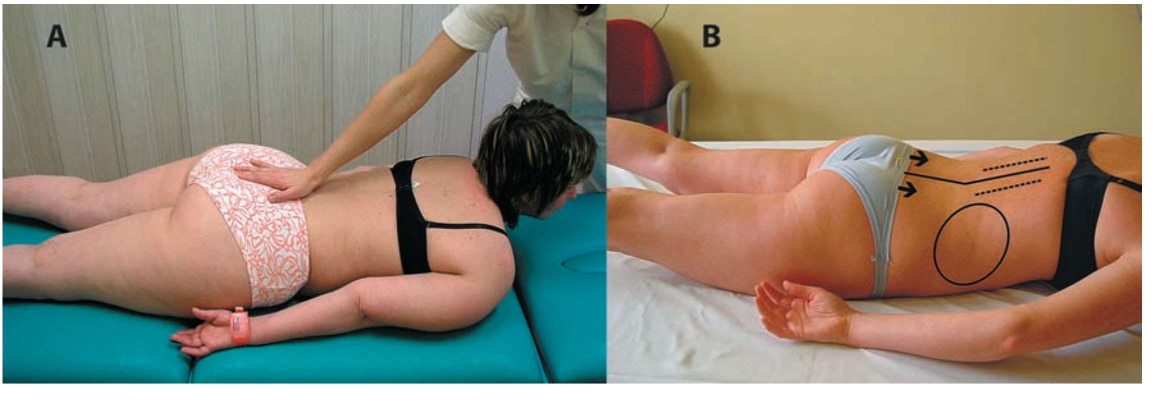

FIGURE 4-23. (A) Trunk extension test, with palpation of the sacrum. The pelvis should maintain neutral position during the test. Postural pelvic instability is indicated if the clinician should feel the patient's sacrum move against his hand in a cranial direction. (B) Abnormal pattern with leg raise: hyperactivity of gluteus maximus, hamstrings, and calf muscles helping to stabilize the trunk during extension and the substitute for insufficient intra-abdominal and intrapelvic pressure regulation. The arrows indicate anterior pelvic tilt, the interrupted lines the hyperactive paraspinal muscles, and the ellipse the hypoactive area.

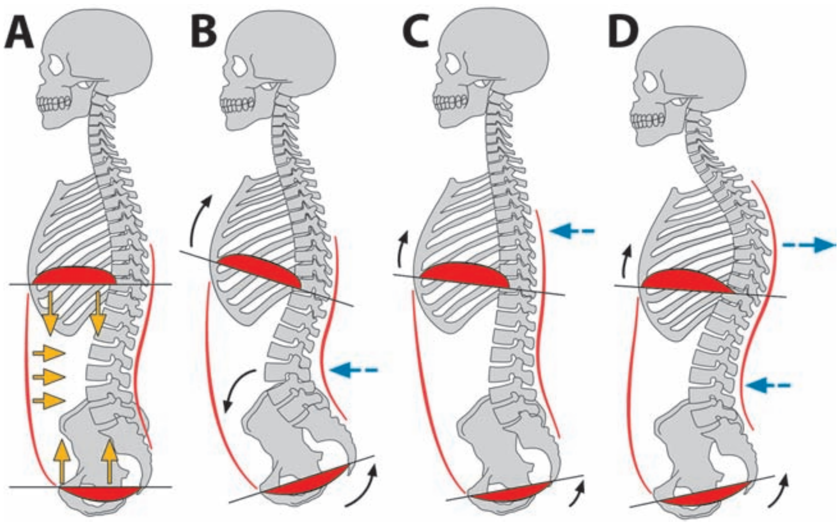

FIGURE 4-24. (A) Physiological position of the diaphragm and pelvic floor. Their axes are horizontal and parallel to one another. (B) "Open scissors syndrome"—oblique axis of the diaphragm and pelvic floor. (C) Forward drawn chest position. (D) Chest aligned behind the pelvis. The light arrows indicate correct muscle activation and direction of increased intra-abdominal pressure from above (diaphragm), below (pelvic floor), and the front and lateral perspective (abdominal wall). The dark arrows indicate movement—abnormal position of the chest and pelvis under pathological conditions. The dashed arrows indicate an abnormal shift of the chest and lumbar spine under pathological conditions.

intra-abdominal contents, thus helping to stabilize lower thoracic and lumbar segments from the front. The following are the most common types of pathologies:

Forward drawn chest position with the chest aligned in front of the pelvis (see Figures 4.24C and 4.25A). This results in constant isometric activity of superficial paraspinal muscles.

Further, chest aligned behind the pelvis (see Figures 4.24D and 4.25C) resulting in a fixed thoracic kyphosis, lack of segmental movement in mid-thoracic segments, rounded shoulders, short pectoralis major (Figure 4.26D,C).

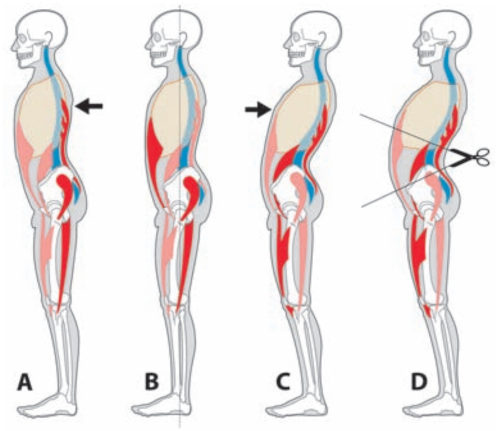

FIGURE 4-25. (A) Forward drawn chest position. (B) Ideal stance position. (C) Chest aligned behind the pelvis. (D) "Open scissors syndrome." The arrows indicate abnormal chest position under pathological conditions.

"Look for open scissors syndrome" (Figure 4.24B and 4.25D), which is the most common postural pathology, with the oblique position of the diaphragm, its anterior attachments more cranial than the posterior attachments (costophrenic part) concurrent with an oblique pelvic axis in sagittal plane as a result of anterior pelvic tilt. This usually is related to lumbar hyperlordosis and hyperactivation of superficial paraspinal muscles. Retraction of the shoulder blades is also a common finding in this syndrome.

Observe muscle tone distribution and contour of the abdominal wall. It should be fairly relaxed when standing. An "hourglass syndrome" can be observed, especially in women. For aesthetic reasons, they perform hollowing of abdominal wall which compromises both, the stabilization and breathing patterns (Figure 4.26B,C).

Respiratory Pattern

Functionally, posture and respiration are interdependent, forming one functional unit (26–30,34,36). Dysfunction in one compromises the other and vice versa. The training of ideal posture must be concurrent with training of the ideal breathing pattern. One of the key prerequisites for physiological spinal stabilization and respiration is the position and dynamics of the chest. Under physiological conditions, the thoracic spine is upright (and elongated), and the chest

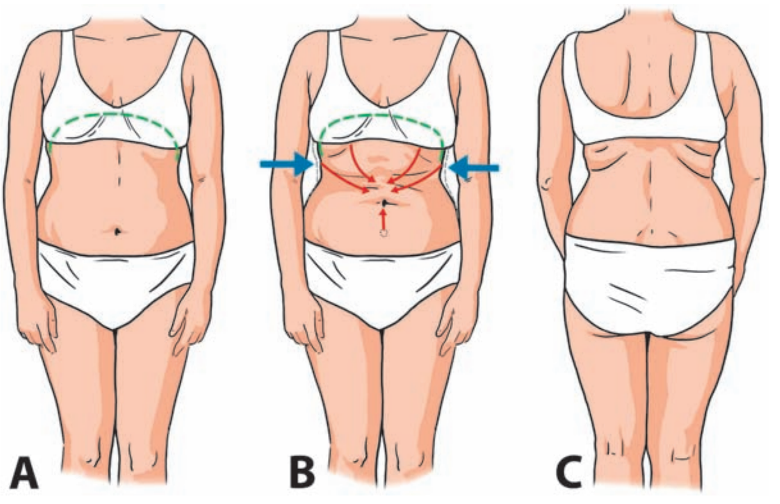

FIGURE 4-26. (A) Physiological contour of the abdominal wall. (B and C) "Hour glass syndrome." The dashed lines in A and B indicate the diaphragm. The thin curved arrows indicate abnormal activation of the abdominal wall, the thin upward pointing arrow illustrates cranial movement of the umbilicus under pathological conditions, and the thick arrows illustrate pathological narrowing of the abdominal wall.

remains in a caudal position during both, inhalation and exhalation (see Figure 4.19B). Accessory respiratory muscles should not be activated for regular, tidal breathing (1,33,34). During inhalation, the lower chest aperture expands proportionally in all directions as the diaphragm drops and flattens out (Figure 4.27A). The clavicles should have a slight upward slope (25°–29°); horizontal position maybe a sign of short (hyperactive) accessory respiratory muscles. Under pathological conditions, the diaphragm is not flattening adequately; it stays in an oblique axis. Excessive cranial/caudal movements can be observed at the sternum (Figure 4.27B).

Between 4-6 weeks of age, when the infant starts to lift the head against gravity when prone or lifts the legs when supine, the diaphragm starts to develop a dual function, simultaneous postural and respiratory function. Physiologically, with every postural activity (both, during breathing and breath holding), the diaphragm descends and flattens out. Its attachments on the lower ribs are stabilized by abdominals, and the centrum tendineum is pulled caudally toward the lower ribs (Figure 4.28B). With dysfunction, however, the diaphragm does not descend adequately during postural activities; the direction of muscle activity reverses and is pulled toward the centrum tendineum (Figure 4.28A), clinically resulting in the "hourglass syndrome" (Figures 4.26B,C and 4.28A).

Testing the Stereotype of Respiration

Supine

The patient is in the hook-lying position or with legs lifted above the table (90° flexion at hips and knees), with the lower legs supported.

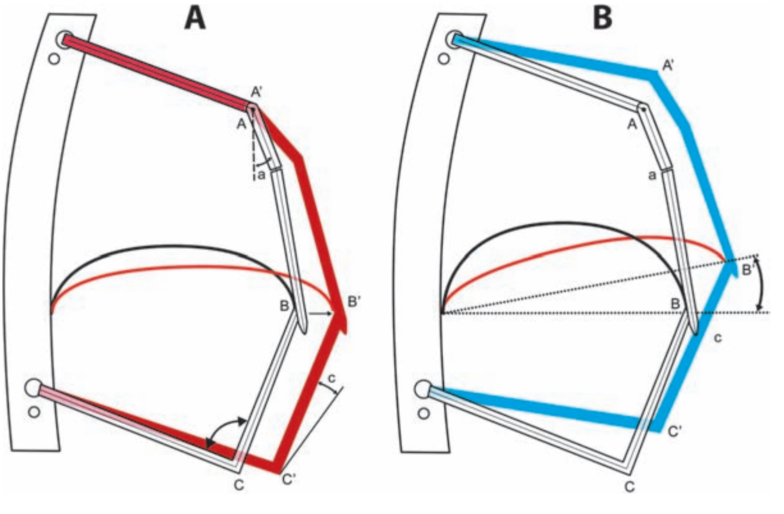

FIGURE 4-27. (A) Healthy breathing pattern. The diaphragmatic axis is almost horizontal. During inhalation, the diaphragm moves caudally while the sternum moves anteriorly. There is proportional expansion of the lower chest (widening of the intercostal spaces). (B) Pathological stereotype of ventilation; the axis of the diaphragm is in an oblique position. The entire chest moves cranially with inhalation and caudally with exhalation with minimal or absent expansion of the lower chest (narrowed intercostal spaces). The lower chest cavity is "locked" with shallow inhalation, subsequently placing increased demands on the accessory muscles of respiration.

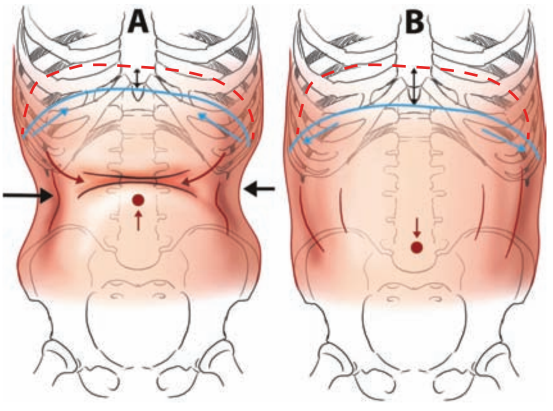

FIGURE 4-28. (A) Pathological postural diaphragmatic activation in the "hour glass syndrome." There is insufficient flattening of the diaphragm and direction of muscle activity toward the centrum tendineum (central tendon), with stiffness of the lower chest and disproportional activation of the abdominal wall toward the umbilicus. The upward pointing dashed arrow indicates a pathological cranial position of the umbilicus. The curved dashed arrows indicate pathological concentric activation of the abdominal wall. The medium arrows indicate abnormal contraction of the diaphragm toward the centrum tendineum. The thick black arrows indicate pathological narrowing of the abdominal wall. (B) Physiological postural diaphragmatic activation: The diaphragm moves caudally, with its attachments fixed and stabilized on the lower ribs by the abdominals; intercostal spaces widen as the lower chest expands, and there is proportional activation of all the sections of the abdominal wall. The medium arrows indicate the correct diaphragm contraction toward the lower ribs (centrum tendineum descending). The dashed arrow indicates the correct neutral position of the umbilicus. In both (A) and (B), the double-ended arrows demonstrate diaphragmatic excursion (greater in B, the physiological case, than in A, the abnormal one).

Observe tidal breathing pattern. Watch and/or palpate accessory respiratory muscles. The muscles should be relaxed. The clavicles should not move cranially and caudally during breathing. Palpate the sternum; it should not shift cranially with every inhalation. The sternum normally remains in a caudal position in the transverse plane during both, inhalation and exhalation.

Palpate the lower intercostal spaces on the lateral aspects of the chest; these spaces should expand or widen with every inhalation.

Palpate the laterodorsal sections of the abdominal wall; these areas should expand with every inhalation. Palpate the abdominal wall above the groin; these areas should expand with every inhalation.

Manually bring the chest (sternum) passively to a caudal position (see Figure 4.19B). While maintaining the sternum in a caudal position, instruct the person to take a breath. The sternum (and your hand) should not be pulled cranially.

Sitting

The same principles apply as for the supine position.

The patient is sitting facing the clinician, with arms and legs relaxed (Figure 4.29). Palpate above the groin and instruct the patient to take a deep breath as if to "breathe into or push against your fingers." During inhalation, the abdominal wall should expand ventrally, caudally, and laterally.

The clinician is behind the seated patient. Palpate posterior aspects of the lower intercostal spaces on both sides and instruct the person to take a deep breath (Figure 4.30). You should feel simultaneous and symmetrical expansion of the lower chest (dorsally and laterally) and widening of the intercostal spaces. There should not be any cranial movement of the chest or trunk.

The clinician stands behind the seated patient. Palpate the laterodorsal aspects of the abdominal wall just below the lower ribs (see Figure 4.30). Instruct the person to breathe in and breathe out. After a full exhalation, instruct the patient to push against your fingers. This is a test for postural function of the diaphragm. The clinician should feel symmetrical and strong expansion of the abdominal wall against his fingers. The expansion is proportional in all directions. If the person is facing the mirror during this test, you should also see ventral expansion of the lower chest and the abdominal wall. Hollowing of the abdominal wall is a sign of abnormal stereotype and paradoxical activation of the diaphragm (see Figures 4.26B and 4.28A).

FIGURE 4-29. Palpate above the groins (arrows): Ask the patient to breathe into your fingers and/or to push against your fingers. In both cases, you should feel strong symmetrical activation (lateral, anterior, and caudal) while the umbilicus is stabilized (i.e., not pulled cranially and inward as on the picture where you can see pathological pattern) and the patient should remain relaxed.

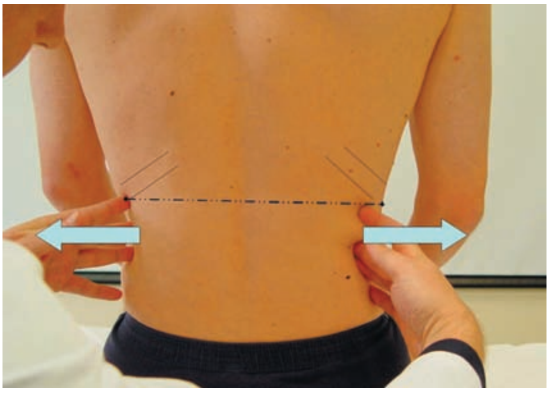

FIGURE 4-30. Diaphragm test. Palpate lower intercostal spaces and below the lower ribs. Ask the patient to breathe into your fingers and/or push into your fingers (arrows; inspiratory diaphragmatic activity) while holding their breath (purely postural activity of diaphragm). In both cases you should feel a strong symmetrical activation. There should not be any concomitant thoracic spine flexion synkinesis or shoulder elevation during the test.

How to Train Optimal Breathing

Begin the training in a supine position with legs bent and feet supported on the table or floor. Place your hands on the side of the patient's lower rib cage and guide the patient how to bring the chest down (see Figure 4.19B). Bring the patient's chest down with your hands (spine should stay in contact with the floor and not flex forward). While inhaling, the patient must expand the lower chest wall sideways toward your hands, keeping the neck and shoulder muscles relaxed as much as possible. When exhaling, allow the chest to relax passively without any contraction of the abdominals. If relaxation of the abdominals during exhalation is difficult, ask the patient to place his/her hands on his abdomen for feedback to monitor for excessive tension.

Progression in Exercise Complexity

All the principles described above should be considered for any exercise prescription in any initial position (lying, sitting, standing, quadruped, oblique sitting, etc.). Regardless of the exercise position, the quality and the pattern of sagittal stabilization require adequate muscle coordination and balance under physiological conditions.

We recommend to begin training in basic, that is, the easiest positions (4.5 month developmental age, prone and supine) in order to reset muscle coordination for deep intramuscular core stabilization (see Figures 4.18A and 4.20A). Any basic position can be advanced by applying resistance and/or by adding limb movement (see Figure 4.16). The amount of applied resistance and the amount of movement have to be matched to the patient's ability to stabilize the core—spine, trunk, pelvis—without any compensatory movement. The same principle is applied in higher, advanced, or more challenging positions. There are three options to utilize developmental positions during training: 1) training in a particular developmental position itself, 2) training in a transitional phase from one developmental position to another (e.g., from supine to side-lying, from oblique sitting to quadruped), or 3) training only a specific segment of the locomotion phase (e.g., initiation of turning process).

Dynamic Neuromuscular Stabilization Principles for Exercise

The lower the position of the patient to the ground or table, the easier the exercise. For example, it is usually easier to train the proper stereotype of breathing (or any movement, e.g., throwing) in supine than in a quadruped position.

The higher the position is, the more unstable the person becomes; thus, the exercises become more challenging. Hence, progression of the exercise should proceed from lower, more stable to higher or more unstable positions.

For any type of exercise, always choose positions where the person can properly maintain sagittal stabilization and breathing stereotype. If the person exercises with an incorrect stereotype of stabilization and breathing, the pathology will be reinforced as a result of the exercise (see Figure 4.17).

To further challenge the physiological stereotype of stabilization, resistance (e.g., barbell) to the dynamic movements of extremities can be introduced or added. The resistance must be adequate to the person's ability to properly stabilize. If an abnormal stereotype of stabilization or breathing is observed, the resistance should be reduced (see Figure 4.17).

Loading up of the weight-bearing zones can/will assist in stabilization.

Centrate the supporting segments.

To make the exercise more challenging, reduce the number of supporting segments (e.g., in bear position the person is asked to lift one leg or arm, or both contralaterally) (Figure 4.42C,D).

Exercise in various positions (e.g., the tennis player may train the stroke in supine, oblique sitting, or tripod positions).

Have the person focus on the exercise for the purpose of training body awareness.

SAMPLE EXERCISES

Basic Exercises

Supine Position (4.5 Months)

This position corresponds to the position of a 4.5-month-old infant in supine and having the ability to lift its legs

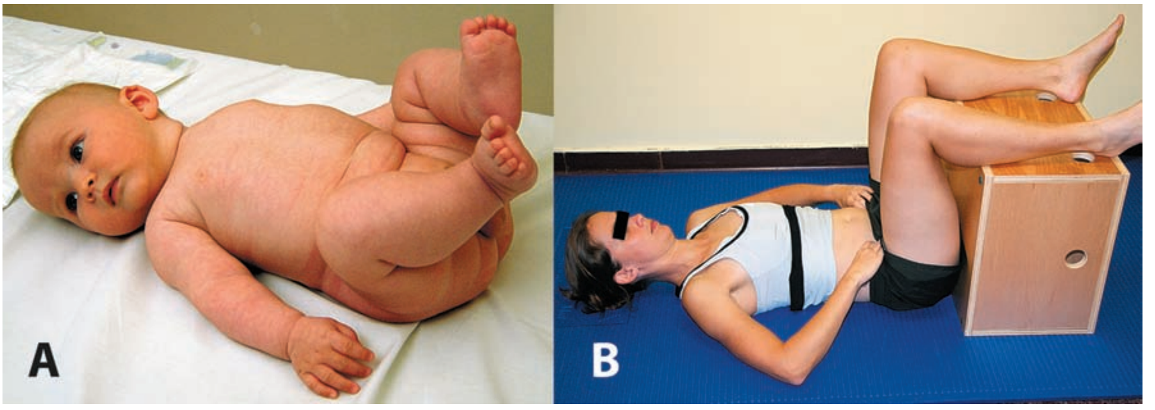

FIGURE 4-31. (A) A 4.5-month-old infant can already hold the legs above the table while stabilizing the core. (B) Basic supine exercise, based on 4.5 months developmental position, with legs supported.

above the table up to 90° in hips and knees (Figure 4.31A). This is a fundamental position for further advanced positions and movements (see Figure 4.31B). All the trunk muscles (abdominals, back muscles, diaphragm and pelvic floor) are well coordinated for integrated spinal stabilization, which is a basic prerequisite for any movement.

Initial Position

In the supine position, the head, chest, spine and pelvis are in a neutral position (see Figure 4.31B); the head is supported on the nuchal line, the neck is neutral, the entire spine maintains contact with the table (floor) without hyperextension. The axis of the chest and the pelvis is parallel and perpendicular to the ground. The shoulders and arms are relaxed. The hips and knees are flexed to 90 degrees. Start with the legs supported under the calves and progress by removing leg support (Figure 4.32).

Exercise Performance

After a few regular breaths, bring the chest into a relaxed position toward the hips. Take a normal breath and direct the breath into the pelvis (pelvic floor). Use your hands to make sure the inhalation goes as far as the groin and increas muscle tension in this area as a result of both, inhalation and voluntary activity. Keep repeating this activity while still breathing in and out. Gradually, lift one leg and then the other leg away from the support. Repeat 3–5 times as long as all body parts are coordinated and maintained in the proper position. You can make the exercise more challenging by moving the legs alternately into extension.

Exercise Errors

These include elevation of the shoulders (shoulder protraction), head and neck hyperextension, chest and rib cage elevation, the belly button being drawn in, using excessive effort, and/or holding the breath.

FIGURE 4-32. Basic supine exercise with legs unsupported. Make sure the hips are well centrated during the entire exercise (90° flexion and slight external rotation at the hips). Support or weight bearing is at the level of the upper gluteal muscles. The exercise should be discontinued if the back arches into extension or if the subject is unable to maintain the hip and knee position.

Modification in Supine Position with Thera-Band (Figure 4.33)

Initial Position

The position is identical to the basic supine exercise. Thera-band is wrapped around the shins (just under the knees), crossed from the front to the back side, and brought forward around the thighs (just above the knees). The band is held in the palms (wrapped twice), with the free end placed between the thumb and the index finger. Elbows are flexed to 90 degrees. (Figure 4.33A).

Exercise Performance

Maintain the basic supine position with the head, spine, trunk, and pelvis in a neutral position. Breathe into the area above the groin. Supinate your hands while performing external rotation at the shoulders (see Figure 4.33B).

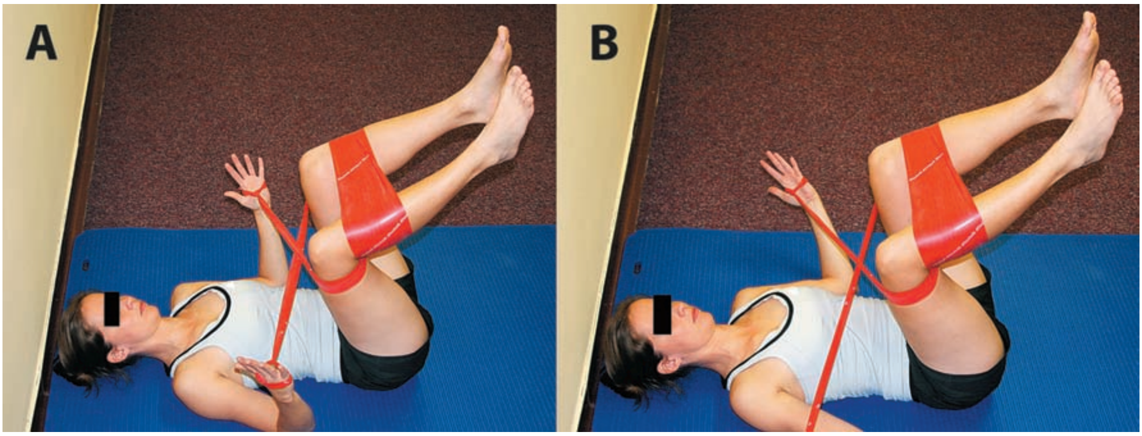

FIGURE 4-33. Modification of basic exercise in supine using resistive band. (A) Initial position. (B) Exercise performance, with supination and external rotation of the arms against the resistance of the band.

Exercise Errors

These include holding your breath, spine extension, chest elevation, and hip and knee internal rotation.

Prone Position (4.5 Months)

A healthy 4-month-old infant in prone is able to bring its elbows in front of the shoulders, support itself on the medial epicondyles, and lift the head with an upright cervical and upper thoracic spine (Figure 4.34A). This movement is feasible only when the posterior and anterior muscles of the torso work in proportional coactivation (see Figure 4.12) and the shoulder girdle muscles are well coordinated with serratus anterior and the diaphragm to maintain the shoulder blades in a neutral position, "caudal position."

Initial Position

Prone position with elbows in front of shoulders at the level of the ears and the head supported on the forehead (see Figure 4.34B).

Exercise Performance

Position the shoulders caudally and broadly (not retracted). Trunk is supported at the level of the symphysis or ASIS. Lift the head slightly with cervical and upper thoracic spine upright; the movement should initiate in the mid-thoracic spine between the shoulder blades (see Figure 4.34C).

Exercise Errors

These include hyperextension of the neck (Figure 4.35A), elevation and/or protraction of the shoulders, retraction of the shoulder blades (Figure 4.35B), hyperextension of the T/L junction or lumbar spine and anterior pelvic tilt (see Figure 4.23B).

Modification in Prone Position

Initial Position

The elbows and the forehead are supported on the end of the table, with the lower torso and pelvis lying on a gym ball and the feet resting freely on the floor (Figure 4.36A).

Exercise Performance

Slightly depress the shoulders and press the elbows onto the bench, lift the head slightly from the bench, and press the pelvis slightly into the gym ball (see Figure 4.36B).

FIGURE 4-34. (A) Ideal model of 4.5 months prone position. (B) Basic prone exercise, based on 4.5 months developmental position. Initial position. (C) Exercise performance: Lift the head with cervical and upper thoracic spine upright; the movement should be initiated at the mid-thoracic segments (between the shoulder blades [arrow]).

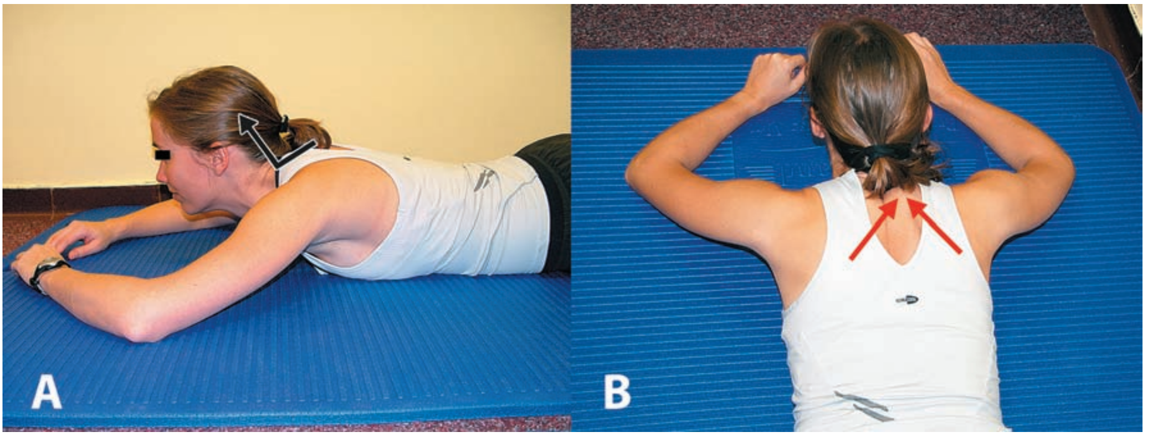

FIGURE 4-35. Poor performance and movement pattern of head extension. (A) Neck hyperextension, with kyphosis of cervicothoracic junction (arrow). (B) Retraction of the shoulder blades (arrows).

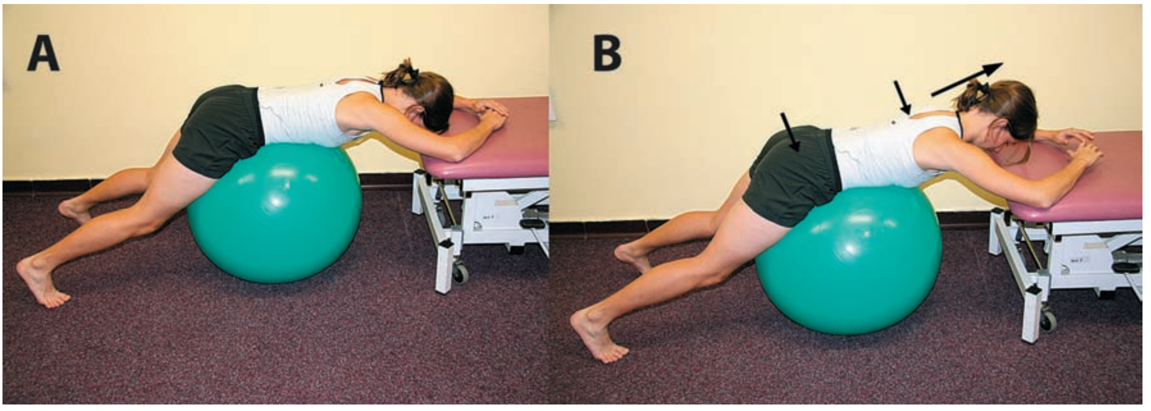

FIGURE 4-36. Modification of basic prone exercise. (A) Initial position with elbows supported on the end of a bench or table, with the lower torso and pelvis supported on the gym ball. (B) During exercise, the head is lifted from the bench with extension starting at the mid-thoracic spine and the pelvis is slightly pressed into the gym ball (arrows).

Exercise Errors

These include shoulder elevation, hyperextension of the lower thoracic and lumbar spine, and flexion of the lumbar spine with posterior pelvic tilt.

Side Sitting Position (7 Months)

This exercise trains the stabilizing function of the supporting shoulder and the functional interplay between the muscles of the shoulder girdles and the lower torso.

Initial Position

This corresponds to the side sitting position of a healthy 7-month-old infant, when the forearm is used for support (Figure 4.37). For exercise, the support is on the forearm (the elbow is located under the shoulder) and on the side of the buttock. The top leg is supported in the front of the

FIGURE 4-37. Healthy 7-month-old infant, showing side sit with support on the forearm. This position is a snapshot of the movement transition from supine or sidelying to quadruped.

FIGURE 4-38. (A) Initial side sitting position with the top leg supported on the medial condyle of the knee. (B) Trunk rotation with the top arm elevated, with the top leg still supported on the medial condyle of the knee. (C) Lifting the pelvis in side sitting position; support is shifted from the buttock toward the lateral condyle of the knee (arrows) of the bottom leg.

bottom leg on the medial side of the knee (Figure 4.38A) or on the foot (Figure 4.39A). The entire spine is straight, including the neck and the head.

Exercise Performance

The bottom shoulder is pulled down away from the head. The top arm is raised above the shoulder and the entire trunk rotates forward (Figures 4.38B and 4.39B). Support on the buttock shifts toward the knee (Figures 4.38C and 4.39C). Repetition is performed 3–5 times only as long as all body segments are coordinated and kept in the proper position.

Exercise Errors

The bottom shoulder is elevated and protracted and/or the spine is not uprighted (hyperextended or sagged).

Modification: Side Sitting Position with Hand Support

Initial Position

This corresponds to the oblique sitting position with hand support of an 8-month healthy infant (Figure 4.40A). The supporting hand is placed in line with the pelvis next to the supporting buttock. The bottom leg is semi-flexed at the hip and knee, the top leg is supported on the foot placed in front of the bottom knee. The spine is straight (see Figure 4.40B).

Exercise Performance

Keep the shoulder of the bottom arm depressed and raise the other arm. Lift the pelvis from the supporting position and weight bear on the bottom knee and the foot of the top leg. Movement continues in the forward direction by rotating the torso toward quadruped posture (see Figure 4.40C,D).

Exercise Errors

These include shoulder elevation, spine extension or flexion, weight-bearing elbow hyperextension, and/or the disproportional weight bearing of the supporting hand (overloading of the hypothenar and insufficient weight bearing of the thenar).

Advanced Exercises: Higher Postural (Developmental) Positions

Quadruped Position

The position on all fours is the initial position for crawling when an infant reaches the age of about 9 months (Figure 4.41A). This exercise is important for maintaining straightening of the spine while the extremities are stabilized in a closed kinetic chain. This quadruped position is useful for athletes to train their ability to straighten up the

FIGURE 4-39. (A) Initial side sitting position with the top leg supported on the foot. (B) Trunk rotation with arm reaching forward (the top leg is supported on the foot). (C) Lifting the pelvis in a side sitting position support is shifted from the buttock toward the lateral condyle of the knee of the bottom leg. The arrows on the supporting side indicate that the scapula is fixed in a caudal and abducted position. Note the pattern of scapular stabilization—the lower (supporting) scapula is in caudal position adhering to the rib cage, its medial border parallel with the spine (not elevated or winging).

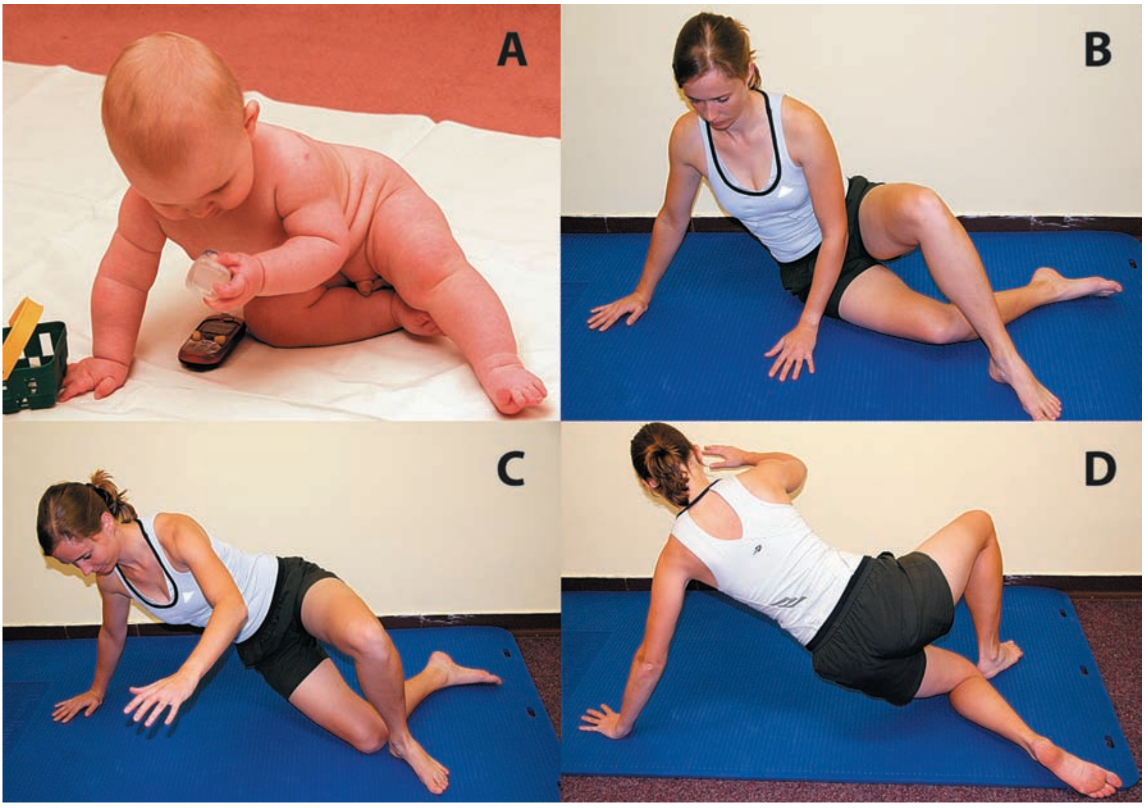

FIGURE 4-40. Side sitting position with hand support. (A) Oblique sitting position in a healthy 8-month-old infant. (B) Initial position for exercise. (C) Exercise performance—lifting the pelvis and loading the bottom knee (front view). (D) Exercise performance—shoulder girdle stabilization. The shoulder blade should not be winging (posterior view).

FIGURE 4-41. Quadruped exercise. (A) Quadruped (crawling) position in a healthy 9-month-old infant. (B) Quadruped exercise—initial position. (C) Exercise performance—shifting the trunk forward and backward.

spine with activation of the shoulder, hip, and trunk stabilizers (abdominals, back muscles, diaphragm and pelvic floor).

Initial Position

In order to perform good quality of quadruped position and crawling, the body segments must be properly aligned: the shoulder girdles are positioned over the well-supported hands in a fully loaded neutral/centrated position: weight distribution must be proportional on all metacarpophalangeal joints (equally on the thenar and hypothenar areas). The hip joints are in slight external rotation, positioned above the supported knees, while the shins and feet converge. The entire spine and the trunk are upright (see Figure 4.41B).

Exercise Performance

Push the right hand and left knee (and shin) down to the support and hold for a few seconds. Do the same on the opposite side. Repeat 3–5 times only if the body alignment is correct.

Move the trunk forward and backward 3–5 times. At the same time, keep the shoulders away from ears and focus on elongation of the spine (see Figure 4.41C).

Exercise Errors

These include elevation and protraction of the shoulders, sagging of the torso, extension (lordosis) of the spine, hyperextension of the elbows, and/or disproportional weight bearing through the hands.

"Bear" Position

"Bear" position is a natural transitory position of an infant older than 10–12 months (see Figure 4.42A). The infant uses the "bear" position to transfer from kneeling to squat and to stand up. This exercise is useful to train shoulder stabilizers with a coordinated interplay of the trunk and pelvic muscles.

Initial Position

The support is on hands and feet. The hands are loaded equally on the thenar and hypothenar aspects, shoulders are aligned above the hands, feet are supported on forefeet or on the entire soles (advanced version), and the knees and hips are slightly flexed with the pelvis positioned higher than the head. The spine is elongated without any associated flexion or hyperextension (see Figure 4.42B).

Exercise Performance

Push the right hand and the left foot down to the floor and keep the spine as straight as possible at the same time. Do the same on the opposite side. Repeat a few times.

Push the right hand and the left foot down to the floor and slowly lift the opposite hand and/or foot, while maintaining uprighting of the entire spine and neutral position of the chest at all times (see Figure 4.42C,D).

Exercise Errors

These include disproportional weight bearing of the hands with overloading of the hypothenar aspect and supination of the forearm, elevated and protracted shoulders, sagging

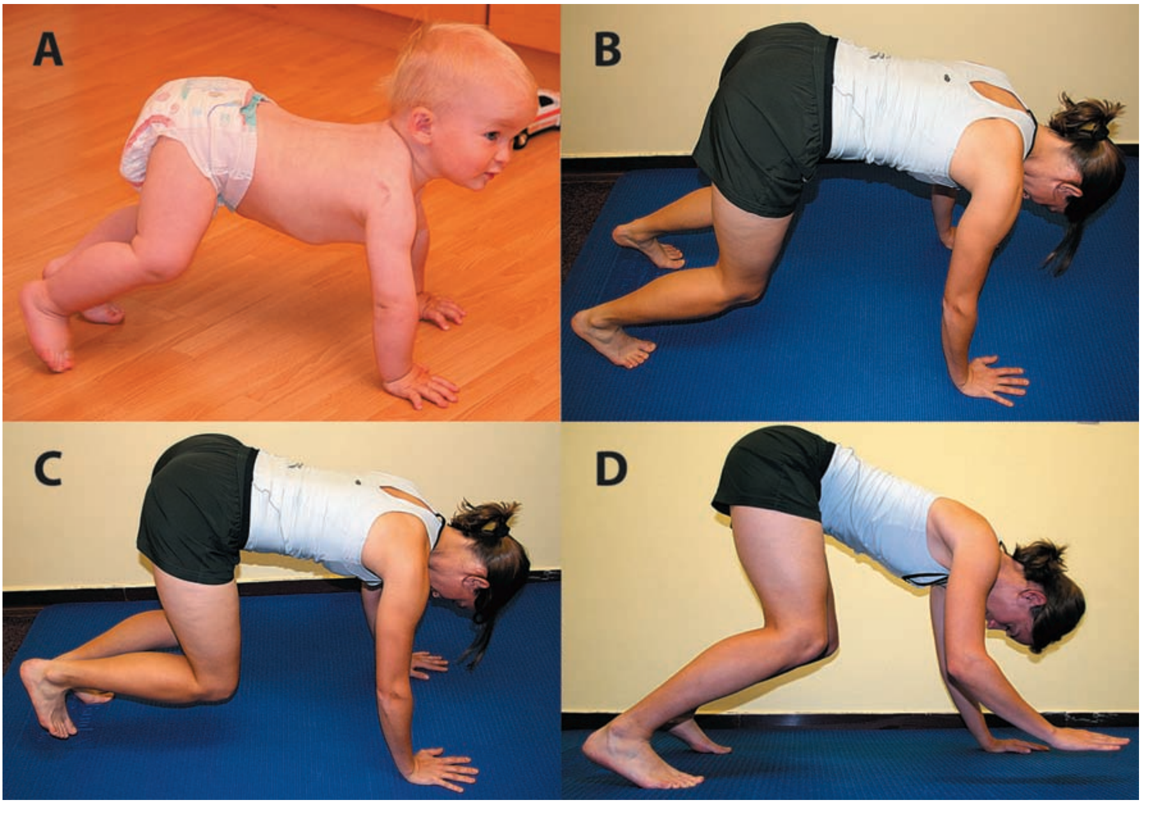

FIGURE 4-42. "Bear" exercise. (A) "Bear" position in a 12-month-old healthy infant (transition from quadruped to standing). (B) "Bear" exercise—initial position. (C) Exercise performance—lifting one leg, while keeping the spine straight and the pelvis level. (D) Exercise performance—lifting one hand while keeping the spine straight and the shoulders level.

trunk, the spine in kyphosis or extension (lordosis), internal rotation at the hips with the knees turned in (valgosity of the knees), disproportional loading of the feet with medial aspect overloaded, and the pelvis dropped on the side of the lifted leg.

Squat

The squat is a transitory or play position for an infant older than 12 months (Figure 4.43A). This exercise is used for training coordination of trunk and hip muscles (ideal training of coactivation between the diaphragm and the pelvic floor). Precise body alignment and focused movement are very important.

Initial Position

It is necessary to stand with the feet apart and positioned at hips' width. The spine, chest, and pelvis are in a neutral position (see Figure 4.43B,C).

Exercise Performance

Perform the movement slowly, with the spine upright and the knees aligned above the big toes (the knee must not shift forward). Gradually, lower the hips to the level of the knees while keeping the arms relaxed at the side or slightly reaching forward. Maintain the posture for a few relaxed respiratory cycles, while directing the inhalation to the lower and lateral part of the chest and down toward the pelvic floor (like "inflating the pelvis") (see Figure 4.43B,C).

Exercise Errors

These include internal rotation at the hips while the knees "cave" into valgosity, anterior pelvic tilt, spinal kyphosis (or lordosis), "inspiratory chest position," and elevated and protracted shoulders.

Dynamic Neuromuscular Stabilization Exercise Modifications for Sports Techniques

Throwing

Prone Exercise on Gym Ball with Bilateral Hand Support

Initial Position

Lie prone over a gym ball and roll forward and reach with the hands to the point when the thighs or the knees are supported on the ball. The head, spine, and the pelvis are kept in a horizontal plane (Figure 4.44A). This position trains basic core and scapular stabilization prerequisite for throwing motion.

Exercise Performance

Move the body forward on stabilized hands as far as you can; keep the spine upright, the shoulder blades adhered to the rib cage, and the chest in neutral position and aligned parallel with the pelvis at all times (see Figure 4.44B). Repeat the rocking forward and backward movement a few times. Make sure your hands are weight bearing proportionally throughout the whole exercise to prevent overloading of the hypothenar part of the hand.

Exercise Errors

These include chest or torso sagging down, elevated shoulders, pelvis that drops into an anterior tilt position, and cervical hyperextension.

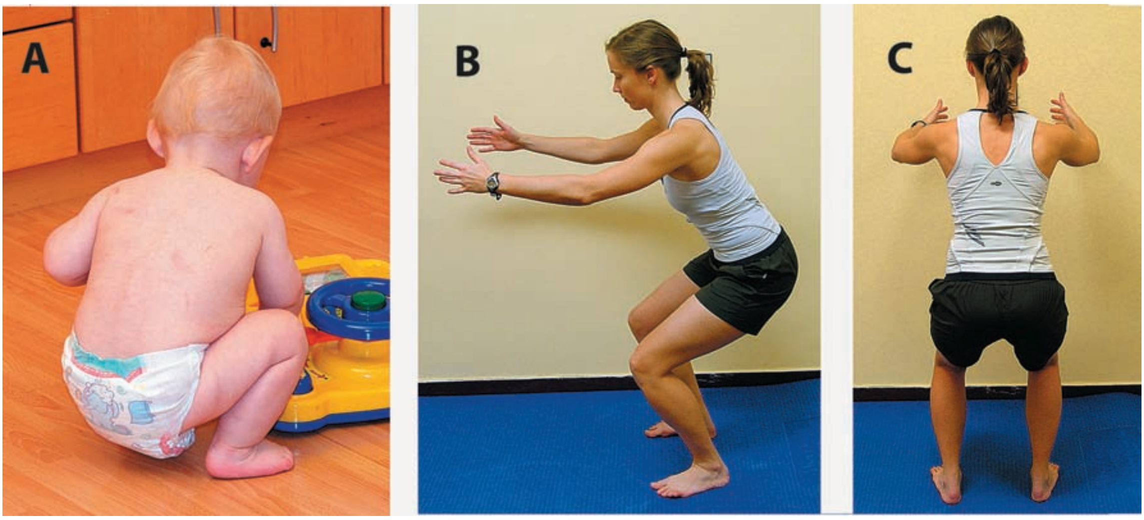

FIGURE 4-43. Squat exercise. (A) Squat position in a 12-month-old healthy infant. (B) Squat exercise—while keeping the back straight, breathing is directed to the lower and lateral parts of the chest (side view). (C) Squat exercise (posterior view)—avoid scapular retraction, forward drawn chest position, and anterior pelvic tilt.

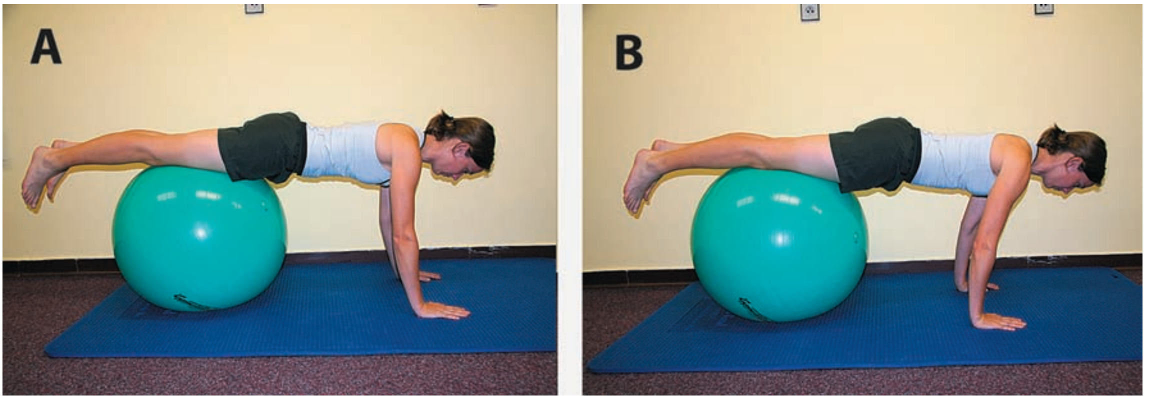

FIGURE 4-44. Prone exercise on gym ball with bilateral hand support. Initial position, with hands on the floor and legs supported on the gym ball. (A) Shoulders aligned above the hands. (B) Exercise performance—shifting the body forward on fixed hands, keeping the entire body level.

Side Sitting with hand support (See Side Sitting Position, Figure 4.40) can also be used to train optimal muscle coordination in order to achieve stabilization prerequisite for throwing movement

Exercise with Thera-Band in a Standing Position (Forearm and Knee Support Against Wall)

Initial Position

Stand in a corner and support the elbow and the forearm on the wall. The front leg is slightly bent at the knee and slightly pressed against the wall, whereas the back leg is extended at the knee and loaded on the entire foot—equally on the lateral and medial side (Figure 4.45A).

Exercise Performance

Attach the Thera-band (attached behind) to the free hand and pull it forward at various angles and planes of shoulder elevation (see Figure 4.45B–D).

Exercise Errors

These include shoulder elevation, retraction of shoulder blades, spinal hyperextension or hyperkyphosis, chest elevation or "inspiratory position of the chest," and valgosity of the knee and the hip of the supporting leg.

Kicking

Basic Supine Exercise with Legs Unsupported and Alternately Moved into Extension (See Supine Position Fig. 4-32)

Lunge and One-Leg Stance

Initial Position

This involves standing with a good centration of the feet—equal amount of weight bearing and neutral position of the pelvis, trunk, and entire spine.

Exercise Performance

Lunge forward with the right leg and swing the left arm forward and the right arm backward to a horizontal level (see Figure 4.46A). Shift the body weight forward to the right leg and extend the knee. In this position, swing the left leg forward to bend the hip and knee to 90°, while bringing the left arm backward and the right arm forward (see Figure 4.46B). Perform a few slow repetitions on each side.

Exercise Errors

These include hyperextension of the spine, "inspiratory" or forward-drawn chest position, "caving in" of the knee and the hip of the lunging leg, the knee of the supporting leg shifting past the big toe (the knee should be aligned above the big toe), and shoulder elevation while swinging the arm.

Jumping, Taking Off

The following already described techniques can be used to train stabilization coordination as a prerequisite for jumping and taking off: Lunge and One-Leg Stance (Figure 4.46)

Squat (See Squat, Figure 4.43)

Lunge on the Step and Taking Off

Initial Position

Lunge forward on the right leg (or the nondominant one for taking off) onto a step at about the height of the left knee. The knee is positioned over the ankle (Figure 4.47A).

Exercise Performance

Load the right foot and unload the left foot from the heel as the left foot is only supported on the toes while maintaining equal weight bearing on both sides of the lunging foot. When weight bearing on the lunging foot, swing both arms up and forward (see on Figure 4.47B). Repeat this movement 5–8 times slowly, focusing on proportional loading of the lunging foot, knee joint centration, and proper positioning of the torso. The Thera-band can be wrapped around the pelvis and attached behind to resist the lunging movement, making the exercise more challenging.

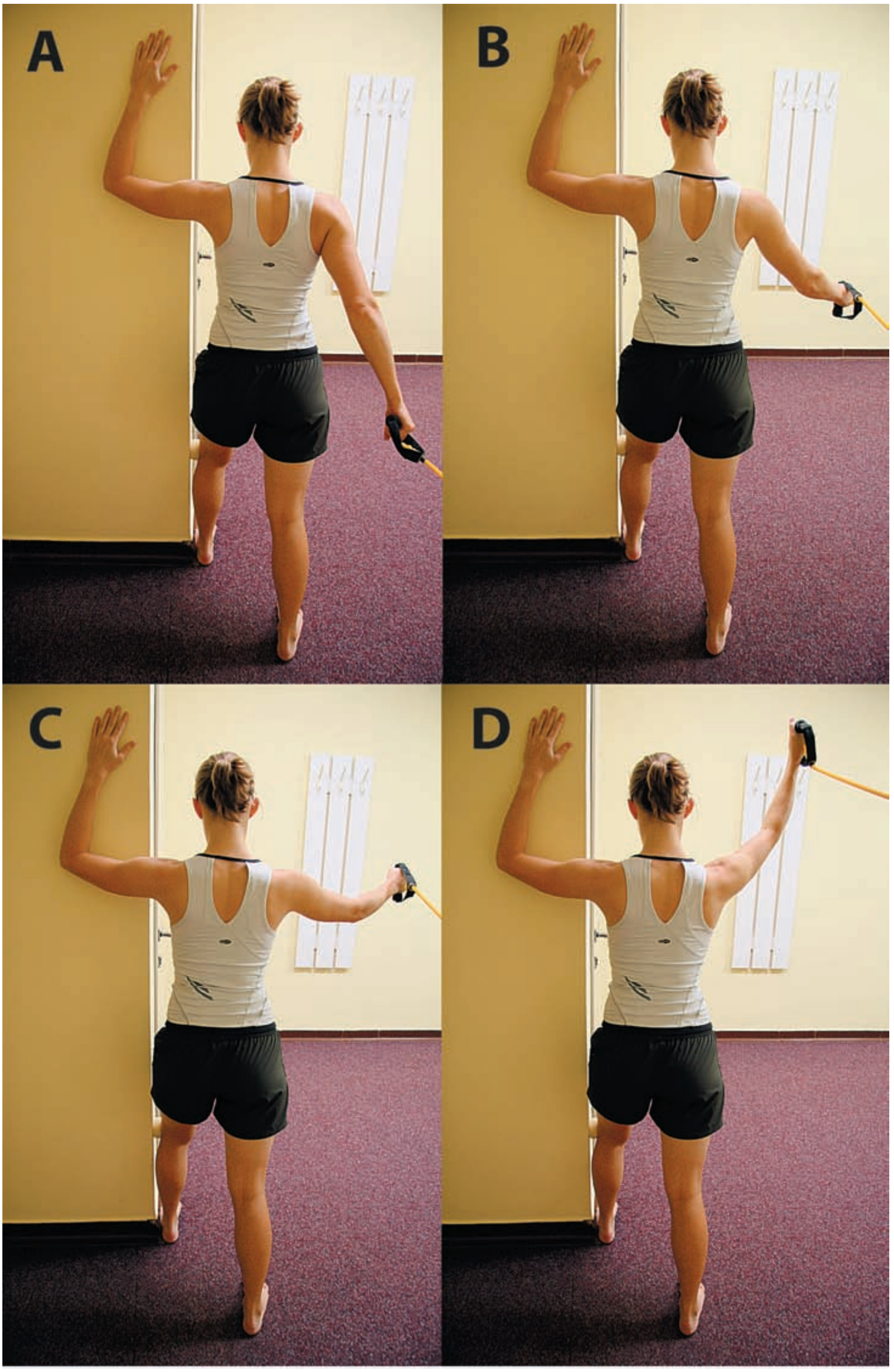

FIGURE 4-45. Exercise with resistive band when standing with one forearm and knee supported against the wall. (A) Pulling the band in the plane of the body. (B) Pulling the band forward with shoulder abducted. (C–D) Pulling the band forward and upward.

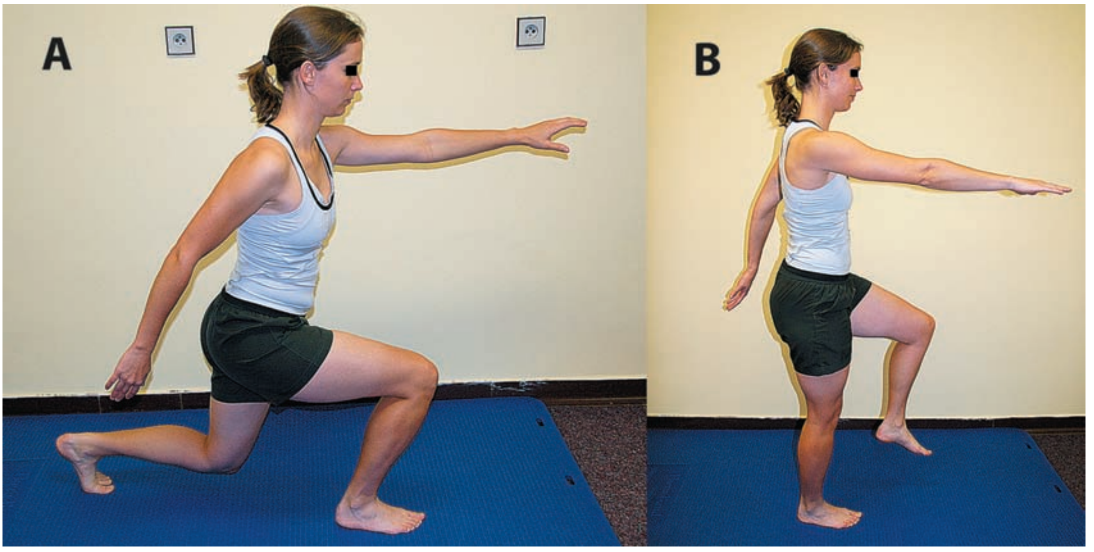

FIGURE 4-46. Lunge—one-leg stance exercise. (A) Forward lunge with reciprocal arm swing. (B) Second phase of the exercise: Switching from a lunge to one-leg stance, while changing the position of the arms.

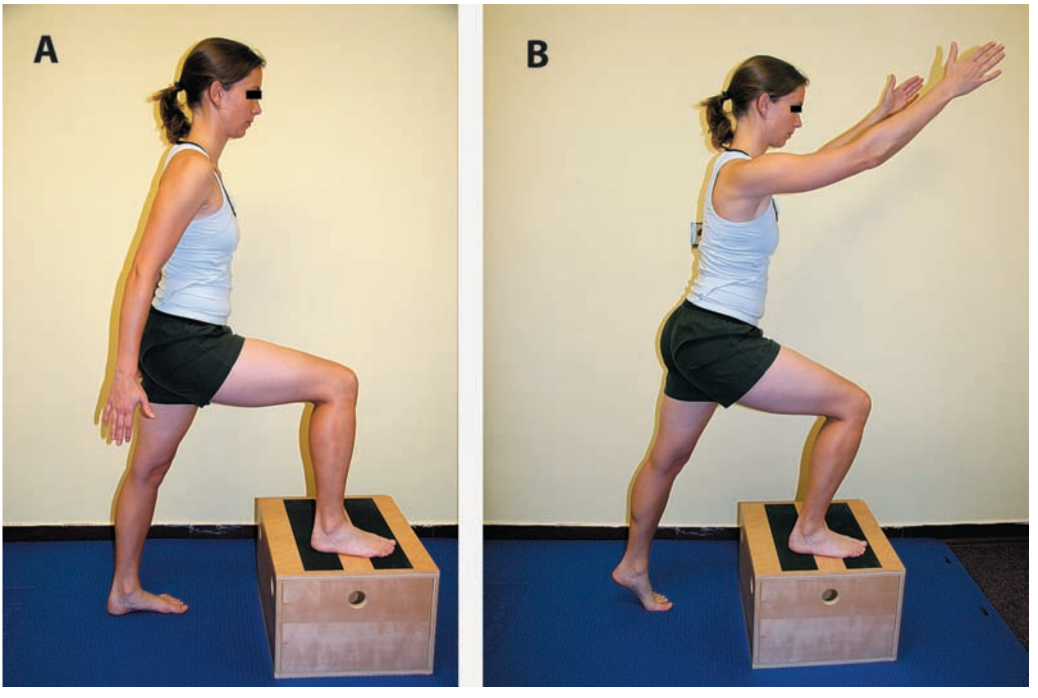

FIGURE 4-47. Lunge exercise on the step. (A) Initial position. (B) Exercise performance—shifting the support from the extended leg toward the lunging leg. Left foot—heel off, weight-bearing lunging (right) foot while swinging both arms forward.

Exercise Errors

These include "caving in" of the knee and the hip of the front leg, the lunging foot not loaded proportionally on both medial and lateral sides, dropping of the nonlunging hip, and an overextended or flexed spine.

Plyometric Exercise

Initial Position

Stand on a step about 30 cm (1 foot) high. Another step 10–15 cm (0.3–0.5 foot) high is placed about 50 cm (1.6 feet) in the front of the first step (Figure 4.48A).

FIGURE 4-48. Plyometric exercise. (A) Initial position. (B) Exercise performance—jumping down from the step with good centration of the spine, hips, knees, and feet. (C) End position of plyometric exercise—after immediate jumping up on the second step.

Exercise Performance

Jump down with both feet between the steps and immediately jump up onto the second step (Figure 4.48B,C).

Exercise Errors

These include chest elevation, anterior pelvic tilt, and a flexed or hyperextended spine.

Shooting (Hockey, Golf)

Bear Exercise (See "Bear" Position, Figure 4.42)

Squat and Twist with Thera-Band

Initial Position

It is necessary to stand with the feet apart, feet and knees pointing out, and the knees slightly bent. The spine is kept upright. A Thera-band is attached to one side and the free part of the band is wrapped with both hands in front of the chest (Figure 4.49A).

Exercise Performance

Rotate the trunk to pull on the Thera-band, while maintaining the pelvis in the original initial position (the pelvis should not rotate!). Keep both feet equally loaded on

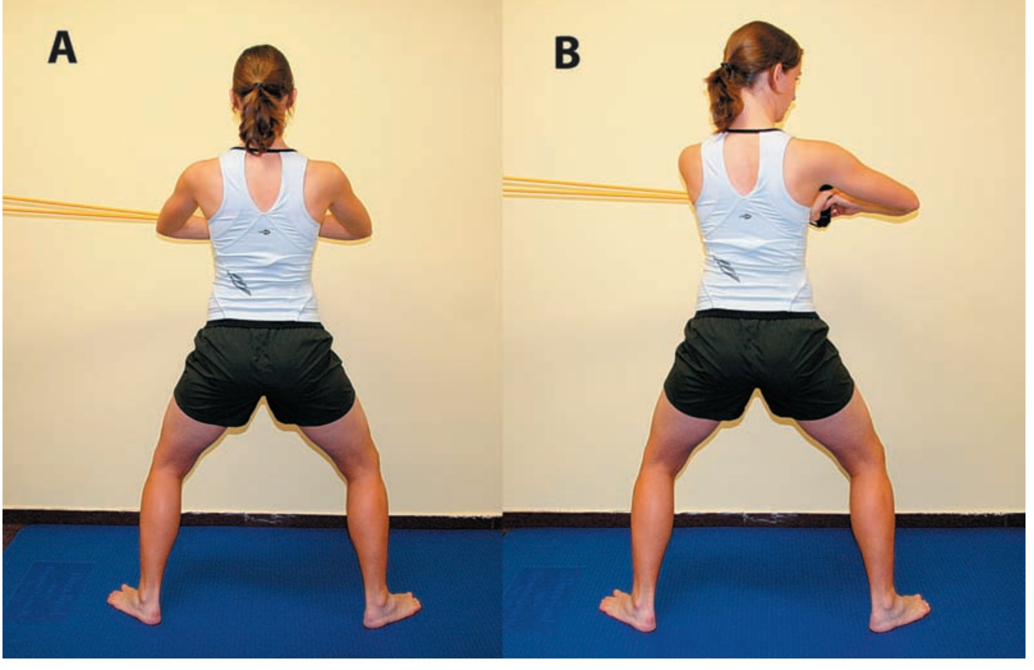

FIGURE 4-49. Squat with trunk rotation against resistance. (A) Initial position. (B) Exercise performance, rotating the trunk while pulling the band.

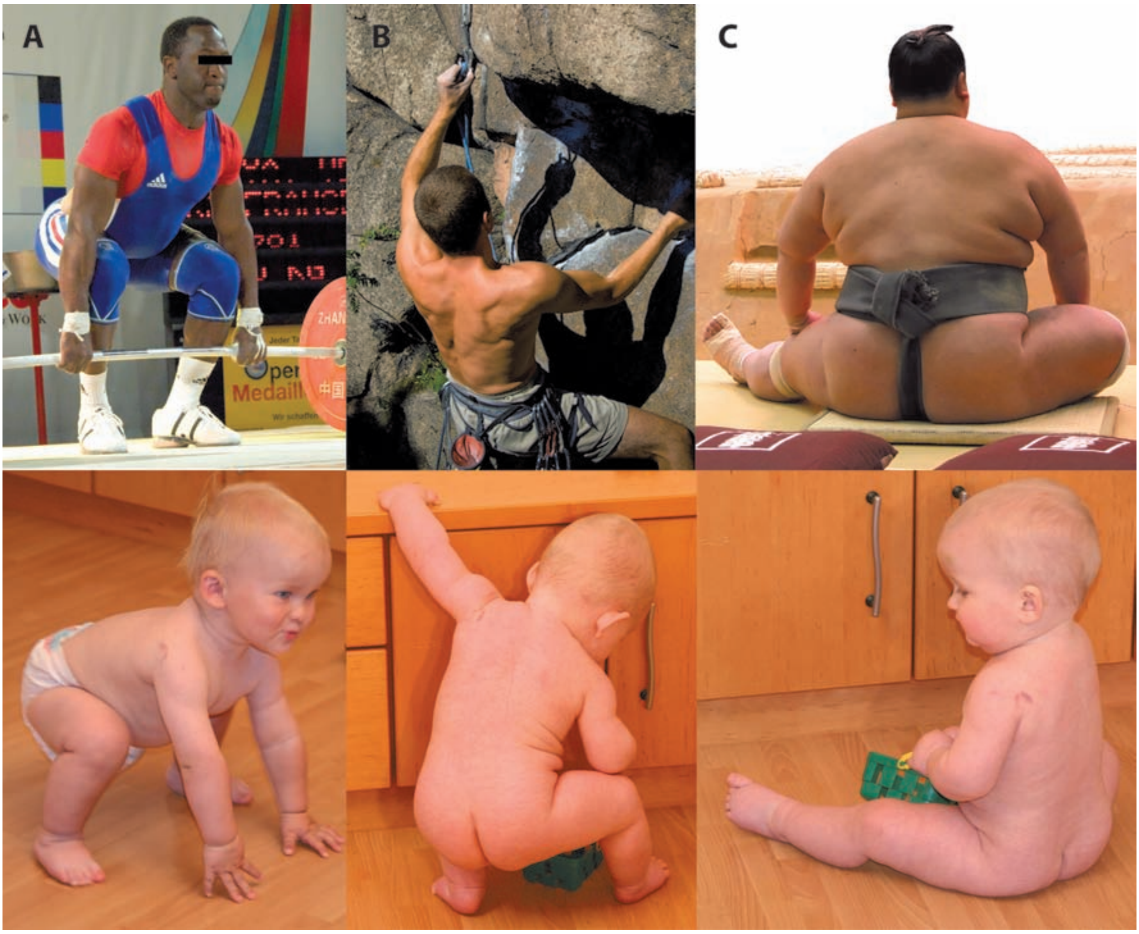

FIGURE 4-50. Comparing the quality of stabilization of and athlete to the one of a healthy infant. (A) Note that the hip, knee, and feet position and stabilization pattern in the weight-lifter and the infant are identical. Note the neutral position of the chest and the shoulder girdles. (B) Note the scapular stabilization pattern (caudal/neutral scapular position) and activation pattern of the lateral and dorsal parts of the abdominal wall are similar in both, the rock climber and the infant. There is no bulging of the lateral abdominal wall unlike the pathological pattern depicted in Figure 4.14A. (C) Note the ideal uprightness of the entire spine in the sitting position of both, the healthy 9-month-old infant and the sumo wrestler. For all of the above six postures, ideal balance between anterior and posterior musculature (including pelvic floor and diaphragm) is necessary.

both lateral and medial sides (see Figure 4.49B). Repeat the exercise slowly or a few times, as long as proper alignment of all body segments is maintained.

Exercise Errors

These include loss of foot contact, rotation of the pelvis, and elevation of the shoulders.

CONCLUSION

During all the exercises described above, DNS principles described in the first two sections of this chapter should be incorporated. In addition to injury prevention, athletes can enhance their sports performance when they understand the developmental principles and functionally centrate the joints during training (Figure 4.50). Those with inadequate body image and compromised functional centration due to pain and protective patterns, anatomical abnormalities, etc., are at higher risk for injuries. Further, their sports performance in terms of maximum speed, strength, and quality will be affected. The ultimate goal of using DNS in both, treatment of athletes and sports training is to stabilize the torso for ideal centration of all the joints for smooth and efficient movement as demonstrated in physiological development.

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