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The Hip Bone is Connected to the Foot Bone...

The hip to foot relationship in energy transfer and conservation

by Erl Pettman, MCSP, MCPA, FCAMT

INTRODUCTION

Gracovetsky pointed out in his classic article 'The Optimum Spine', how, if 'Survival of the Fittest' is truly a workable hypothesis then the term 'fittest' must relate to an organisms ability to minimize its energy consumption as it attempts to survive in, or even dominate its environment. If this is applicable to humans then the species owes its achievement primarily to the unique form of erect bipedal gait, known as striding. Striding is the biomechanical expression of specific anatomical features which exist in no other mammal. Here are some of them:

1) A habitual weight-bearing lumbar lordosis
2) A hip joint which can 'extend' beyond the vertical, coronal plane of the spine
3) The 'Q' angle of the femoral neck (which helps to minimize rotational displacement)
4) A knee joint (with flattened femoral condyles) which 'locks' in two phases of gait i.e., at heel strike (? to absorb impaction forces), and then again through most of the stance phase of gait turning the thigh and leg into a rigid weightbearing pendulum.

While these are interesting anatomical features which are necessary to effect erect, bipedal locomotion they do not in themselves explain why striding is such an efficient form of gait.

In 'The Optimum Spine' and "The Spinal Engine' Gracovetsky proposes that the lower limbs are not essential for human locomotion and underscores this with an unforgettable video of a thalidomide victim 'ambulating' without legs. The lower limbs, he theorizes, merely give us extra leverage which in itself provides an energy-saving device. To improve biomechanical efficiency muscle-induced energy is 'stored' within the collagenous ligaments and capsules of the lumbo-pelvic region and 'released' like a coiled spring as loading is transferred from one limb to another.

If we accept this proposal, which appears mechanically sound, the next question to be answered is what role, if any, do the unique anatomical features of the lower limb play in expediting optimal efficiency during gait?

As inhabitants of planet Earth our bodies are subjected to, and must obey, the Laws of Physics. As unique as we might think we are, we are not exempted from these Laws.

Sir Isaac Newton reminds us that we are under the constant influence of gravity. While giving us a fixed point from which to launch our locomotive efforts (friction) it will penalize any imprudent motion with severe penalty. If we do not maintain our base of support we fall. If we generate excessive torsional ground forces it will fracture bone. Energy cannot be created or destroyed. It can merely

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Notes from the Editor

This issue of the NAIOMT Newsletter highlights a feature article by senior faculty, Erl Pettman, entitled "The Hip Bone is Connected to the Foot Bone". Erl presents a comprehensive biomechanical assessment to locomotion dysfunction based on his years of clinical experience and concepts from the works of Gracovetsky. Other contributors to the newsletter come from NAIOMT faculty members Ed Belding, who provides a "Clinical Pearl" on training the transversus abdominis, and finally a book review by Alexa Dobbs of a text by Dr. David Musinick entitled, "Conditioning for Outdoor Fitness". We welcome your comments on this edition of the NAIOMT Newsletter. They may be emailed from the web site or mailed to NAIOMT, 1574 Coburg Rd. #129, Eugene, OR 97401 Bill Temes

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be transferred from one form to another. For example, chemical (molecular) energy within muscle is transferred to kinetic energy (and heat) and bones move. This kinetic energy must be transferred in one or more of three ways:

1) Ground reaction, or absorption forces (molecular distortion of the Earth's surface)

2) Friction (heat)
3) Stored as potential energy within the tissues of the body (molecular).

Obviously any terrestrial motion must involve all three, but the biological machine that transfers a minimum of energy to ground reaction and friction, and a maximum to cyclical stored potential kinetic energy will be the most efficient, i.e., the 'fittest' to survive.

If striding is as efficient as proposed then there must be mechanisms within our lower limb which minimize ground reaction and friction and optimize storage of potential energy. Gracovetsky postulates again that there are ample 'storage' mechanisms in the lower limb and he cites the capsules and ligaments of the joints as being appropriate. However, his examples emphasize tissues or structures distorted on a sagittal plane. This underscores a very basic misconception in those studying lower limb biomechanics that the primary (and therefore most important) motion of our lower limb joints is in a sagittal plane i.e., those motions that would most effectively propel us forward. However, effective and efficient are totally different concepts. If dysfunction occurs within the machinery of the lower limb is the central nervous system going to initiate de-compensatory changes that make us more effective or more efficient? If survival is the basic aim it must be efficiency that is maintained. Our human genetic code has probably not been programmed yet that some of us wish to be Olympians, or that not all of us have an inexhaustible supply of nutrition and water.

For purposes of discussion let us analyze the most basic form of leg-induced, erect, bipedal gait illustrated by a child walking a Barbie Doll. As each leg is placed in front of the other it can be seen immediately that there is a spin, or torsion, of the foot against the ground. Also, the trunk follows the leg by externally rotating with the propulsive leg. At a clinical level one is immediately reminded of the gait initially adopted by the bilateral above-knee amputee. A gait that is amplified when a cosmetic foot is added to the prosthesis. The energy expenditure of these unfortunate individuals must be phenomenal. Huge levels of friction and ground reaction are occurring plus the added burden of actively having to manipulate the non-weight bearing limb forwards. Seeing this cumbersome gait leaves one with the

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impression that if the 'Spinal Engine' is born with legs a severe loss of function in (or absence of) the lower limb cannot be adequately compensated for by the lumbo-pelvic mechanism alone. In part the trunk is propelled forward with minimal lateral displacement by the shoulder girdles and upper spine rotating in the opposing direction through space. Energy efficiency is assisted by the alternating pendular swing of the upper limbs. But how does the role of lower limb structures turn this potentially inefficient gait into striding?

Biomechanical and kinetic energy relationship of the lumbo-pelvic and lower limb joints

At heel strike the pelvis is carried forwards on the weight bearing hip which, if normal offers a mobile Fall 2000 surface of minimal friction. As the hip joint is passively extended the capsule and articular ligaments will ensure that the hip, in turn, is internally rotated. However, to ensure that the trunk is minimally laterally rotated the femur itself must be internally rotating in relation to the ground. The internal rotation of the hip must now be absorbed as potential energy or dissipated (wasted) as ground reaction and friction. This is where motion of the lower limb joints must be more carefully studied. It is noted that the conjunct rotation of the knee and ankle joints is external, so this will offer some moderate de-compensation of the medial rotation descending from above. However, the brunt of medial rotational forces must be absorbed, and stored as potential energy, in the joints of the foot. How does it do this? It is interesting to note that on courses dedicated to the biomechanics of the foot that the role of the mobile, adaptable foot is ascribed to its ability to 'adapt to uneven or malleable ground surfaces'. A brief review of comparative anatomy, e.g., the feet of the mountain goat or camel, would suggest that the human foot is neither designed nor capable of efficiently coping with unpredictable terrain. The frequency of sprained ankles would seem to seem to add clinical doubt also, yet this fallacious statement is common. The most damaging, widely held belief, however, is that the 'arches' of the foot, both lateral and transverse, must be maintained for optimal foot function. As we all know an entire industry, supported by our own profession and others, including shoe manufacturers, are operating very lucratively under this misconception. The widespread practice of making a foot more rigid by the introduction of orthotic devices, arch supports etc, very often denies the foot the chance to perform its natural absorptive function.

Biomechanical and anatomical analysis of the human foot will lead the observer to see how the foot, biomechanically speaking appears to be two feet in one! On one side is a very mobile 'lateral foot' supported by very strong ligaments. This includes the sub-talar joint, the calcaneo-cuboid joint, the cubo-metatarsal joint, 'supported' by the sub-talar posterior interosseous ligament and the long and short plantar ligaments. In contrast is the much more rigid 'medial foot' including the talo-navicular joint, cuneonavicular joints, inter-cuneiform joints, cuneo-meta-tarsal joints and the 1st metatarso-phalangeal joint. Ligamentous 'support' of this region appears somewhat lacking compared to its medial partner.

This, in itself should raise questions. If the medial foot (and arches) indeed requires support to be rigid, why aren't the larger ligaments on the medial side of the foot? If the lateral metatarsal arch is so important why doesn't it have adequate ligamentous support?

Did Mother Nature mess up again, leaving us superintelligent humans to clean up the mess? It reminds me of a paper I once read (too long ago to remember its author) berating natural selection for giving us an upright posture, which of course, requires a higher blood pressure which in turn is responsible for heart disease, strokes and varicose veins. More likely, it has just taken us a rather long time to understand this magnificent machine's true function. Do

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ligaments only restrict or modify joint movements, or are there some whose functions, in addition to this, have the inherent capacity to store significant amounts of potential kinetic energy, perhaps a major component in making our gait the model of efficiency that it undoubtedly is? This would require significant elasticity, rather than plasticity. A comparative study of the 'Young's Modulous of elasticity' of various ligaments would certainly help answer this question.

Lateral foot phase - ENERGY ABSORPTION

It is proposed that between heel strike and heel lift the internal rotation from the hip joint is absorbed by the external rotation of all joints distal to it. Such a motion is clearly demonstrable in the knee and ankle joints. In the foot, however, because the longitudinal axis of its bones is aligned at right angles to the bones of the leg proper, a different terminology is employed. External rotation is expressed in an abduction (valgus) motion of the foot joints.

Rotation around the longitudinal axis of the foot bones differs from 'medial' to 'lateral' foot. The tar-sal bones in the lateral foot will rotate medially, those on the medial side will rotate laterally. This will ensure that the metatarsal arch is decreased, a necessary motion in the foot's 'flattening', absorptive phase of gait. A metatarsal arch support will significantly impede this motion. Immediately after heel strike the sub-talar joint begins to evert and once forefoot loading of the 4th and th metatarsal heads is complete the anterior progression of the line of gravity, coupled with the descending medial rotation from the hip, move the calcaneocuboid and cubo-metatarsal joints towards close-pack. This combination of motions tightens the posterior sub-talar interosseous and the long and short plantar ligaments, storing potential kinetic energy.

As weight-bearing dorsi-flexion of the ankle progresses the wedge-shaped talus is forced into the ankle mortice. This forces the fibula superiorly fixing the superior tibio-fibular joint. As it does so the fibular bends (especially in the lower one third) increasing tension in the tibio-fibular interosseous membrane. Is this an example of stored potential energy in an osseous structure? The peroneus longus now has a fixed, stable origin and a fixed pulley in the form of the cuboid through which the upward pull of peroneus longus can be transferred into a downward pull on the first ray bringing the 1st metatarsal head, or rather its sesamoid bones, to the ground. This sesamoid placement is essential if load transference and efficient toe-off are to be completed successfully.

The medial foot phase - PROPULSION

As weight-bearing dorsi-flexion of the ankle reaches close-pack continued forward displacement of the tibia, together with the innate tension within the gastrocnemius, lifts the heel. This releases the lateral foot from close-pack and the stored potential kinetic energy within the lateral foot 'spring' helps to propel the medial foot into its 'twisted' position of plantar flexion, adduction and internal rotation. This twist is further enhanced by the release of potential kinetic energy stored in the hip and knee joint during close-packing. An external rotational force is now dominant from above.

Ultimately, the now rigid first ray bears the brunt of loading. To minimize the friction (and, therefore, the transfer of kinetic energy into ground reaction and heat) the 1st metatarsal head surfaces glide and rotate on the 'set' sesamoids. If appropriate setting of the sesamoids has not been achieved this loading and lateral torsion will interact with the ground on the medial side of the 1st metatarsal head rather than its articulating condyles, not only dissipating (wasting) kinetic energy but eventually dislocating the sesamoids, creating a reactive periostitis (bunion), and permanent adduction displacement of the hallux. Collectively we identify this series of dysfunctions as hallux valgus. Further, adequate transfer of loading and torsion to the 1st metatarso-sesamoid articulation is achieved by the fact that the

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combined length of the 1st metatarsal and sesamoids is greater than the 2nd (or 3rd) metatarsals. Improper placement of the sesamoids means that, effectively, the 1st metatarsal becomes 'shorter' than the 2nd. The structure of the 2nd metatarsal is totally inadequate to bear the loading and torsion to which it is now subjected and a spectrum of biomechanical disintegration will ensue. This compensatory disintegration produces effects which amazingly, over time, have been identified as isolated dysfunctions:
1) metatarsalgia 2) Morten's neuroma 3) stress fracture of the 2nd metatarsal 4) aseptic necrosis of the 2nd toe.

Clearly the hallux valgus syndrome and the 2nd metatarsal 'syndromes' have a common cause, i.e., delayed or inappropriate placement of the 1st MTP sesamoids, the origins of which can be so variable it may include a lumbar nerve root palsy (L5 or S1), loss of knee close-packing, ankle mortice instability, etc., etc. This set of well recognized signs and symptoms with a multiplicity of causes is analogous to the 'diagnosis' of fibromyalgia, except, unlike fibromyalgia the varying multiplicity of causes can be identified by Fall 2000 curate assessment. Such an assessment, however, must be based on a knowledge of what is demanded of the lower quadrant both anatomically and biomechanically.

Assuming that the metatarso-sesamoid function is normal, the production of a rigid first ray can be seen as a further energy-saving device. During the swing-through phase of gait, as the angle between the weight bearing and non-weight bearing femora increases, gravity would ensure that there would be a tendency for the trunk to descend. Control of, and restoration from this vertical displacement would require muscular effort and high energy expenditure. To control and counter this passively, and therefore efficiently, the limb 'length' is effectively increased by the plantar flexed, rigid 1st ray.

In SUMMARY

The concept of kinetic energy 'storage' within the osseo-ligamentous structures of the lumbo-pelvic mechanism during the stance phase of gait, released on weight transference, to perpetuate efficient forward momentum appears to mechanical validity. However, to maintain efficiency requires that this released 'spring' mechanism has a secondary storage mechanism within the osseo-ligamentous mechanisms of the lower limb. This appears to be achieved by the kinetic energy being 'absorbed' by internal rotation of the hip and, in turn stored in the conjunct rotation of the joints distal the hip. For optimal energy transfer a horizontally wound spring requires a horizontally orientated reciprocating spring. The primary candidate for this appears to be the foot whose ability to abduct, or externally rotate, can adequately match the internal rotation of the hip. A mathematical relationship is therefore envisaged between the amount of horizontal rotation generated by the lumbo-pelvic mechanism being matched by the amount of internal rotation generated by the hip, which, in turn, is matched by the external rotation (abduction) possible in the joints of the lower limb, distal to the hip, especially those within the foot.

'Body type' versus environment

Given the variability of body 'types' it must be assumed that an individual who matures with a less mobile, flatter lordotic spine will develop a stiffer, more rigid lower limb and vice versa. In assessment of architectural design it is clearly seen that a patient who has bilateral 'cavus'(twisted or supinated) feet invariably has a more varum knee, less mobile hip (in extension and internal rotation) and a flatter lordosis. The individual with a sway back has very mobile hips, a tendency towards genu valgum and very flat feet. For the purpose of this paper the former will be referred to as 'rigid' and the latter, 'loose' These are two ends of a very colorful spectrum of human architectural norms, and if all aspects of their lower quadrant anatomy fit into one of these particular 'patterns' it must be considered as normal for that individual.

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Remember the original tenet of this paper is that the 'fittest' are those who most efficiently cope with their environment. It should never be assumed that all humans come with the same 'equipment' or that their environment is the same. In a society where it is taught that a 'All men (individuals) are created equal' it is forgotten that this political ideal does not carry through to an (impossible) anatomical ideal. How many white, or Caucasian, sprinters compete in the 100 meter Olympic finals? How many black swimmers do you see in any Olympic event? Certain physical or physiological characteristics are clearly more adapted to certain activities.

In sport the 'rigid' individuals body favors sprinting and jumping activities. The 'loose' individual's anatomy favors activities which require more 'body torque' e.g., golfing and discus throwing. But sport is not our predominant challenge much of the time. At work, standing on a concrete floor, working on a conveyor belt assembly job, or a cashier at the local supermarket requires absorption of loading and torsional stresses. The 'loose' individual will accommodate to this environment admirably, but the 'rigid' individual will have a much greater biomechanical challenge.

Understanding that certain body types are more (or less) suited to differing environments help to explain how the patient may have no relevant biomechanical dysfunctions at all to account for their back, knee or foot problems. Instead, it may well be that this individual has chosen an environment that is inappropriate for his lower quadrant 'body type'.

So it would appear that the manual therapist's first problem is to decide what is normal for that individual, both in respect to their potential adaptive biomechanical potential, and their perceived 'normal' environment. A 'rigid' body type does not favor jogging but anybody who has dealt with an habitual jogger knows that persuading a jogger to adapt to alternative activity is futile. Jogging for most individuals appears to be as much a psychological release as it is a need to keep fit. Past experience justifies this point of view as we treat patients who, with clear evidence of tibial stress fracture, patients refuse to stop jogging, and scoff at our suggestion to maybe swim, or work out in the gym, as an alternative exercise program. Faced with the fact the patient's inherent anatomy (or psycho-somatic demands on it) cannot be changed, we are faced with counseling the patient to change their environment. This may be as simple as advising them to run on a more adaptive surface e.g., soft earth trails, or may require more technical advice regarding footwear. All of this, of course, assumes that no relevant biomechanical dysfunctions are detected.

Primary lower quadrant dysfunctions affecting striding efficiency In the absence of obvious, recent trauma painful foot malfunctions most often result from a primary proximal musculoskeletal dysfunction and may be categorized as:

1) Joint hypomobility

A loss of hip extension/internal rotation actually alleviates the rotational demands on the distal lower limb joints. However, it will severely limit the amount of energy transfer from the lumbo-pelvic mechanism leading to hypermobility, or even instability, within these joints. The most profound change from an energy point of view is the uneven, functional 'length' of the two lower limb pedula. This seems most efficiently countered by a decreased stride length bilaterally, which is obvious on observation of gait.

Loss of full knee extension, ankle dorsi-flexion or sub-talar eversion will significantly limit rotational kinetic energy storage within these joints and must be de-compensated by increased dorsi-flexion and abduction in joints distal to the dysfunction. If the resulting hypermobility exceeds the foots adaptive potential then pain will result. This is observed as a flat, abducted mid- and fore-foot, often referred to as a fore-foot valgum. To distinguish between a ‘fixed’ valgum deformity and an adaptive de-compensation weight-bearing tests

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must be employed. Comparison is made between the erect ‘torsional’ test and the semi-squat to toe-raise test. If, during either of these tests, the foot can reverse its resting position i.e., it can come into a twisted (varus) position then this is a clear indication that the fore-foot is adapting to some proximal dysfunction.

Loss of a 1st ray joint plantar-flexion/adduction will lead to de-compensatory hypermobility both proximal and distal to the dysfunction. More importantly there is delayed or inappropriate setting of the sesamoids leading, ultimately, to the hallux valgus or 2nd metatarsal ‘syndromes’ mentioned earlier.

A loss of extension/adduction at the 1st metatarsophalangeal joint leads to an abnormally increased length of the weight-bearing limb, and is expressed as a vertical ‘limp’. It is extremely difficult to de-com-pensate since only one (stiff) joint is distal to it and de-compensation is achieved by increased rotational friction of the hallux.

2)Joint instability The most commonly occurring (but least commonly detected) instability of the lower limb must be the unstable ankle mortice. An almost inevitable consequence of a moderate to severe sprained ankle

this dysfunction incapacitates the talus’s function as load/torsion ‘distributor’. This leads to minimal latFall 2000 eral foot loading and premature medial foot loading with delayed and improper metatarso-sesamoid placement. Hallux valgus or 2nd metatarsal ‘syndromes’ are inevitable. The less common medial-knee and sub-talar joint instabilities will have the same result.

Instabilities within the joints of the medial foot, especially the 1st ray, effect the passive formation of a rigid lever and muscles must be employed to assist stability. The most appropriate candidates are the tibialis posterior and peroneus longus muscles whose directions of pull are opposing. This may lead to over-use (rapid changes) or exhausted adaptive (insidious changes) tendonitis.

3)Neuro-muscular deficit

1 Since so little muscular effort is employed in striding (after inertia has been overcome) it might be assumed that muscular weakness, from whatever cause, would have minimal effect on intrinsic foot function. On the other hand, if optimal efficiency requires minimal muscular effort, whatever muscular effort is expended it must be utilized because it is essential. Obviously a foot-drop severely affects total lower quadrant function, but little intrinsic foot de-compensa-tory dysfunction. It is the far less obvious losses of tibialis posterior and peroneus longus strength that can cause severe foot dysfunctions. A loss of tibialis posterior tone (from nerve palsy or spontaneous rupture) leaves the resting position of the foot excessively flat and abducted. Even standing becomes a challenge to inert foot structures. During gait, weakness of this muscle may lead to early medial foot loading and potential instability from heel lift to toe-off. A loss of peroneus longus strength primarily affects the foot in delayed and inappropriate st metatarso-sesamoid placement with the inevitable hallux and 2nd metatarsal sequella.

A routine lumbar scanning examination will not only discover these muscular deficits but will go a long way in their differential diagnosis. For this reason alone the performance of a lumbar scan must be considered mandatory in any assessment of foot dysfunction.

Treatment When anatomical degradation is the result of exhausted adaptive potential through biomechanical de-compensation, the therapist’s course of treatment is clear. Fix the culprit not the victim! This may include anything from treatment of a disc protrusion to manipulation of an inter-tarsal joint. Temporary orthotics or taping may be utilized to alleviate symptoms while the central nervous system reverses the de-compensatory mechanisms.

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In cases of articular instability or nerve palsy such lesions may be irreversible. Orthotics may now be essential. Using a passive support to substitute for a loss of inert or muscular support now makes sense. The main question now is which function are you substituting or enhancing, and which type of orthotic is most energy efficient?

In closing, the central nervous system, presumably, has an overriding biological mandate that locomotive efficiency dominates over anatomical integrity. If this is so, then biomechanical de-compensation of a motion lesion to realize improved energy efficiency, in spite of any resulting anatomical deterioration and pain, is acceptable. The clinician who does not accept this, or who believes in restoration of some mythical structural ‘norm’, is doomed to frustration. More importantly, ‘successful’ symptomatic treatment may condemn the patient’s own body to search for further energy-saving solutions, leading to far reaching biomechanical de-compensations, whose eventual symptomatolgy defies both explanation and treatment.

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Clinical Pearl: Training Transversus Abdominis

There has been recent and exciting literature on lumbar and SI stability by numerous authors (Hodges, Richardson, Hides, Jull, V1eeming, Snijdjers, and Lee). As clinicians, we have incorporated these concepts into our treatment approaches. What follows, is a small pearl that might help in this arena. I like to train the static transversus abdominis component of lumbo-sacral stability by using a pressure transducer device placed at the level of the lumbar spine with the patient supine This gives the patient immediate feedback regarding their lumbar spine position The original devices came from Australia about 5 years ago corresponding with Jull and Richardsons' studies An inflatable trisectional cushion placed under the lumbar spine is connected to a pressure gauge that '
can be seen by the patient and therapist It s a great idea but the price tag was a little steep for our clinic or for my patients to use at home I concluded that the basic design resembled a standard blood pressure cuff so I decided to try it in its place It worked beautifully. As a starting point, I generally bring the blood pressure cuff up to 40 mm Hg with the knees and hips flexed to 90 degrees with the patient lying supine and on a firm surface The size of the cuff will also enhance a good neutral positioned spine Patients are instructed to view the pressure gauge and not allow it to vary more than 5 mm Hg as they performed a "modified Sahrmann" lower abdominal progression They really appreciate the feedback from the device and many purchase a blood pressure cuff on their own so they can practice at home Of course, I counsel them regarding other common compensations for the transverse abdominis (I e holding breath, protrusion of rectus abdominis, elevation of shoulders off of table, etc)

If you want to purchase the more sophisticated version they are marketed as the "stabilizer" by Chatanooga Pacific Pty Ltd , Brisbane, Australia. A recent study published in JOSPT by Hagins, et al1 illustrates the use of this device to measure progress with lumbar stabilization exercises and their affects. I would recommend this source if you would like further information.

ED BELDING

PT, OCS, COMT, FAAOMPT

1.Hagins M, et al. Effects of practice on the ability to perform lumbar stabilization exercises J Ortho SportsPhys Ther, 1999 Sep; 29(9)546-55.

Conditioning for Outdoor Fitness—Book Review

David Musnick, MD Mark Pierce, ATC Published by the Mountaineers, 1999 1001 SW Klickitat Way, Suite 201 Seattle, WA 98134 www.mountaineers.org

This is probably the most comprehensive book of Any one interested in conditioning and especially aerobic and functional strength training available conditioning for specific sports activities will find for the lay person and the healthcare provider. this book most helpful. The book may be ordered Specialists in sports medicine, nutrition, physical directly from Mountaineer Books at 1-800-553-therapy, fitness and athletic training have 4453 contributed to this book. In the first section, these specialists explain the basic principles of training, exercise physiology, nutrition, body posture and efficiency of movement. The most up-to date information on the musculoskeletal and cardiorespiratory systems is also provided. The book is organized into three parts. Part 1 covers basic principles of exercise physiology, aerobic conditioning, nutrition, warm-up and stretching, strength and balance training, posture, planning your conditioning program and training outdoors. Foundations for building endurance, efficiency of movement, and agility, are included in this section. Part III is divided into body regions. Common muscle imbalances and movement faults are described with explanations of preferred methods to functionally train in corrections. This section contains the most current information from the sports medicine and physical therapy fields. There is even a chapter on special issues for the conditioning woman. The chapters in part III, conditioning demands of outdoor activities is described. Specific training techniques for anything from rock climbing to windsurfing are presented. Illustrations clearly demonstrate the concepts and the exercises.

ALEXA DOBBS PT, OCS, COMT, FAAOMPT

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