Managing the Recreational Runner from Head to Toe

Introduction

Sedentary lives affect us. *We are made to move, created for expression, placed in a world that's tactile, in need of exploring and involvement*. One way we can move and explore this big, beautiful, blue and green planet is by running. We are loaded with features literally from our heads to our toes which make us primed for running, which can be beneficial for our entire body from the top to bottom. Let's start from the top.

The Runner's Brain (B.J. Lehecka, DPT)

Treadmill running – not resistance training – results in the growth of new brain cells (adult hippocampal neurogenesis) in adult rats.

In adult rats the exercise needs to be "aerobic and sustained" to generate adult hippocampal neurogenesis. There was no response in resistance training groups.[1]

The growth of new brain cells in the hippocampus (a region implicated in cognitive aging) and the enhancement of spatial memory that is brought on by endurance running is basically an evolutionary safety net for when you have outrun your knowledge - when you have run so far that you no longer know where you are and need to learn, and fast. It's a mechanism that makes information uptake easiest when historically you would have been tired, lost, and at your most vulnerable.

The growth of new brain cells is not unique to rats. Hippocampal neurogenesis has been seen in older human adults in response to aerobic exercise.

In a randomized controlled trial with 120 older adults, aerobic exercise training appeared to increase the size of the anterior hippocampus, leading to improvements in spatial memory. "Exercise training increased hippocampal volume by 2%, effectively reversing age-related loss in volume by 1 to 2 y."[2]

Regular walking is linked to a two-fold reduced risk of developing cognitive impairments.

This study demonstrated for the first time the link between participation in physical activity earlier in life, greater gray matter volume, and the reduced risk for cognitive impairment later in life. After a period of 4 more years, 116 of these adults were diagnosed with either mild cognitive impairment or dementia, but greater gray matter volume associated with physical activity was associated with a two-fold reduced risk of developing cognitive impairment.[3]

Cardiovascular fitness (e.g. running ability), but not muscle strength, is strongly associated with higher cognitive performances.

A study of 1.2 million people shows a strong correlation between cardiovascular fitness and intelligence. Researchers studied Swedish men born from 1950 through 1976 in military service, including 268,496 full-sibling pairs, 3,147 twin pairs, and 1,432 monozygotic twin pairs.[4]

Measures of creative potential significantly increase following 30 minutes of running or fast walking.

Sixty college students participated in an experiment consisting of 3 regimens varying the time when a Torrance Test of Creative Thinking was taken in relation to exercise completion. Measures of creative potential significantly increase following 30 minutes of running or fast walking.[5]

Positive mood significantly increases, and negative mood decreases after a 3-mile run. And your brain at positive is 31% more productive than your brain at negative, neutral, or stressed.[6]

"A specially-devised adjective checklist was completed by 165 regular runners 5-10 minutes before, and immediately after, a 3-mile run. Improvements in mood were greater in women than in men, largely because women experienced a worse mood state than did men before running."[7]

A 6-mile run stimulates an endorphin release equivalent to 10 mg of morphine.

"Twelve long-distance runners were evaluated on thermal, ischemic, and cold pressor pain tests and on mood visual analogue scales. Blood was drawn for determination of plasma levels of beta-endorphin-like immunoreactivity, growth hormone, adrenocorticotrophic hormone, and prolactin. These procedures were undertaken before and after a 6.3 mile run at 85% of maximal aerobic capacity… The results show that long-distance running produces hypoalgesia and mood elevation in man. The effects of naloxone implicate endogenous opioid neural systems as mechanisms of some but not all of the run-induced alterations in mood and pain perception."[8]

A half-marathon induces 73% of "the strongest euphoria imaginable."

"The current affective states before and after running as well as before the resting PET scan were evaluated with Visual Analog Mood Scales… The verbal descriptors at the end of the visual analog scale (VAS) were as follows: *no sadness at all *on the left side versus *strongest sadness imaginable *on the right side. Accordingly, the descriptors for euphoria were no euphoria at all versus strongest euphoria imaginable."[9]

30 minutes of treadmill walking for 10 days produces clinically relevant reductions in depression.

Twelve patients with a major depressive episode according to the Diagnostic and Statistical Manual of the American Society of Psychiatry criteria participated. 30 minutes of treadmill walking for 10 consecutive days produced clinically relevant and statistically significant reduction in depression (reduction of 6.5 points from baseline on the Hamilton Rating Scale for Depression).[10]

Running may be as effective as medication or psychotherapy for reducing symptoms of depression.

"Running has been compared with psychotherapy in the treatment of depression, with results indicating that running is just as effective as psychotherapy in alleviating symptoms of depression (Symptom Checklist-Depression reduction in mean item score of 1.9 [running] vs. 1.6 [therapy]… Blumenthal and colleagues randomly assigned 156 moderately depressed men and women to an exercise, medication, or exercise and medication group. Those in the exercise group walked or jogged on a treadmill at 70% to 85% of heart rate reserve for 30 minutes 3 times per week for 16 weeks. Those in the medication group received sertraline, and a psychiatrist evaluated medication efficacy, assessed side effects, and adjusted dosages accordingly at 2, 6, 10, 14, and 16 weeks… there were no significant differences among treatment groups at 16 weeks… Interestingly, 10-month follow-up of those participants revealed that exercise group members (70%) had significantly

(p = .028) lower rates of depression than those in the medication (48%) or the combination groups (54%)."[11]

A study of 1.44 million people shows being physical active (e.g. running) is associated with an average 20% lower risk of 13 types of cancer.

"Health care professionals counseling inactive adults should emphasize that most of these associations were evident regardless of body size or smoking history, supporting broad generalizability of findings."[12]

Running, even 5-10 minutes per day and at slow speeds (<6 mph), is associated with markedly reduced risks of all-cause mortality. Runners have a 3-year life expectancy benefit compared to non-runners.[13]

If an individual performed the amount of jogging or running the CDC recommends (75 min/week of vigorous exercise), that individual would run/jog a total of 65 hours each year. If this individual lived to be 100 with the same activity level (and some do), starting from age 18 the individual would have spent 5,330 hours running, which equates to 222 days, less than 2/3rds of a year. Given the 3-year benefit gained by running (1068 days), the individual would have made a 480% return on the run/jog time investment! One hour of running, thus, may equate to nearly 5 extra hours of life!

When attempting to promote the positive health behavior of running, for mental benefits research suggests that the focus should be on frequency of exercise rather than duration or intensity until the behavior has been well established.

The addition of self-monitoring techniques may increase awareness of running's benefits and self-efficacy, which is generally reinforcing to the patient. "Physician advice is likely to go a long way toward providing motivation and support for exercise. Follow-up contact may also be important during exercise adoption. While this follow-up may present a time challenge to the provider, less time-consuming interactions such as brief telephone contact and automated telephone contact have been shown to increase adherence to exercise programs"[11]

"The Runner's Brain" References

1. Nokia MS, Lensu S, Ahtiainen JP, et al. Physical exercise increases adult hippocampal neurogenesis in male rats provided it is aerobic and sustained. *J Physiology*. 2016 Feb: 594(7); 1855-1873.
2. Erickson KI, Voss MW, Prakash RS, et al. Exercise training increases size of hippocampus and improves memory. *Proc Natl Acad Sci U S A*. 2011 Feb 15;108(7):3017-22.
3. Erickson KI, Raji CA, Lopez OL, et al. Physical activity predicts gray matter volume in late adulthood: the Cardiovascular Health Study. *Neurology*. 2010 Oct 19;75(16):1415-22.
4. Aberg MA, Pedersen NL, Torén K, et al. Cardiovascular fitness is associated with cognition in young adulthood. *Proc Natl Acad Sci U S A*. 2009 Dec 8;106(49):20906-11.
5. Blanchette DM, Ramocki SP, O'del JN, Casey MS. Aerobic exercise and creative potential: immediate and residual effects. *Creativity Research Journal*. 2005: 17(2);257-264.
6. Achor S. The happy secret to better work. TED talk. Also in *The Happiness Advantage* by Shawn Achor, 2010, Crown Business Publishing.
7. Morris M1, Salmon P. Qualitative and quantitative effects of running on mood. *J Sports Med Phys Fitness*. 1994 Sep;34(3):284-91.
8. Janal MN, Colt EW, Clark WC, Glusman M. Pain sensitivity, mood and plasma endocrine levels in man following long-distance running: effects of naloxone. *Pain*. May 1984;19(1):13-25.

9. Boecker H, Sprenger T, Spilker ME, et al. The runner's high: opioidergic mechanisms in the human brain. *Cereb Cortex*. 2008 Nov;18(11):2523-31.
10. Dimeo F, Bauer M, Varahram I, Proest G, Halter U. Benefits from aerobic exercise in patients with major depression: a pilot study. *Br J Sports Med*. 2001 Apr;35(2):114-7.
11. Craft LL, Perna FM. The Benefits of Exercise for the Clinically Depressed. *Prim Care Companion J Clin Psychiatry*. 2004;6(3):104-111.
12. Moore SC, et al. Leisure-time physical activity and risk of 26 types of cancer in 1.44 million adults. *JAMA Internal Medicine*. May 16, 2016.
13. Lee DC, Pate RR, Lavie CJ, Sui X, Church TS, Blair SN. Leisure-time running reduces all-cause and cardiovascular mortality risk. *J Am Coll Cardiol*. 2014 Aug 5;64(5):472-81.

The Sounds of Running (B.J. Lehecka, DPT)

Music has a way of bypassing the intellect and connecting at a different level than spoken facts. That's why television dramas and movies play songs during meaningful monologues. The Verve in Bittersweet Symphony sings the lyric "I need to hear some sounds that recognize the pain in me." We may not be able to see or feel it, but music has the ability to stir the soul, resonate with our thoughts, minister to our emotions, and fuel our movements.

The research behind music and running is fascinating. Studies on humans, nonhuman primates, and music propose that "there appear to be motivational ties to music that are uniquely human" and we may be "candidates for music-specific adaptations."[1,2] And multiple running studies support this. One study of treadmill running by elite triathletes found that time to exhaustion was nearly 20% longer when running in time to music compared to no music.[3] The athletes were able to run an average of 8 minutes and 33 seconds with music versus 7 minutes and 11 seconds with no music, both at 110% of their blood lactate threshold velocity. Music has also been shown to improve performance during 400-meter sprinting, cycle ergometry, and treadmill walking.[4-6]

Music moves us, and it makes us move significantly longer, faster, with more positive moods, with lower ratings of perceived exertion, and the ability to sing duets with Bono, Jay-Z, Sara Bareilles, and Pharrell Williams.

We've also learned that increasing running cadence by 5-10% is associated with multiple benefits:
1. The hip and knee absorb significantly less mechanical energy.[7]
2. Peak hip adduction and internal rotation moments decrease.[7]
3. Center of mass vertical excursion, braking impulse, and peak knee flexion angle all significantly decrease.[7]
4. Patellofemoral joint force is reduced by 14%.[8]
(https://pbs.twimg.com/media/CdVaTkMW8AABSf2.jpg)
5. Gluteus medius and maximus activity increases during the late swing phase.[9]
6. Pressure and force variables in the heel and metatarsal regions are reduced by 565 body weights*second (BW*s) and 140-170 BW*s, respectively.[10]

Tailored music may be the ideal way to retrain running cadence. One study concluded that running to motivational music with a prominent and consistent beat matched to the runner's cadence will likely produce optimal effects.[11] Spotify, the i-Metronome app, or similar apps will allow you to tap a button to determine the beats or steps per minute of a song or cadence, respectively. There are also multiple websites with lists of song suggestions and their corresponding cadences.

Rhythm is woven into the fabric of the world, how things are, or how things are supposed to be. Our hearts beat with rhythm. Our lungs breathe with rhythm. Even the neurons in our brain oscillate with rhythm. Rhythm is essentially knowing when to play and when not to play, when to be on and when to be off. A study of 446 endurance athletes found that athletes with less than 2 rest days per week during the training season had a 5.2-fold risk for injury.[12] Rhythm is the difference between making music and making sound. Your refrigerator makes sound. U2 and Pharrell Williams make music. If you don't know where the rests belong, you will devastate the song. But given proper rest, noise becomes music, and sound becomes song.

"The Sounds of Running" References

1. McDermott J, Hauser MD. Nonhuman primates prefer slow tempos but dislike music overall. *Cognition*. 2007 Sep;104(3):654-68.
2. McDermott J, Hauser MD. Probing the evolutionary origins of music perception. *Ann N Y Acad Sci*. 2005 Dec;1060:6-16.
3. Terry PC, Karageorghis CI, Saha AM, D'Auria S. Effects of synchronous music on treadmill running among elite triathletes. *J Sci Med Sport*. 2012 Jan;15(1):52-7.
4. Simpson SD, Karageorghis CI. The effects of synchronous music on 400-m sprint performance. *J Sports Sci*. 2006 Oct;24(10):1095-102.
5. Anshel MH, Marisi D. Effect of music and rhythm on physical performance. *Res Q*. 1978 May;49(2):109-13.
6. Karageorghis CI, Mouzourides DA, Priest DL, Sasso TA, Morrish DJ, Walley CJ. Psychophysical and ergogenic effects of synchronous music during treadmill walking. *J Sport Exerc Psychol*. 2009 Feb;31(1):18-36.
7. Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc*. 2011 Feb;43(2):296-302.
8. Lenhart RL, Thelen DG, Wille CM, Chumanov ES, Heiderscheit BC. Increasing running step rate reduces patellofemoral joint forces. *Med Sci Sports Exerc*. 2014 Mar;46(3):557-64.
9. Chumanov ES, Wille CM, Michalski MP, Heiderscheit BC. Changes in muscle activation patterns when running step rate is increased. *Gait Posture*. 2012 Jun;36(2):231-5.
10. Wellenkotter J, Kernozek TW, Meardon S, Suchomel T. The effects of running cadence manipulation on plantar loading in healthy runners. *Int J Sports Med*. 2014 Mar 4.
11. Bood RJ, Nijssen M, van der Kamp J, Roerding M. The power of auditory-motor synchronization in sports: enhancing running performance by coupling cadence with the right beats. *PLoS One*. 2013 Aug 7;8(8):e70758.
12. Ristolainen L, Kettunen JA, Waller B, Heinonen A, Kujala UM. Training-related risk factors in the etiology of overuse injuries in endurance sports. *J Sports Med Phys Fitness*. 2014 Feb;54(1):78-87.

A Runner's Trunk and Respiration (B.J. Lehecka, DPT)

Over 75% of smokers who start running stop smoking.

1000+ subjects who smoked and ran in their first 10K were interviewed one year after the race. 75% of women and 81% of men had quit smoking.[1]

Inspiratory muscle training and inspiratory muscle warm-up can both increase running distance.

"An inspiratory muscle warmup and inspiratory muscle training increased distance covered during an intermittent running test to exhaustion. Although the effect of inspiratory muscle training alone was greater than that of an independent inspiratory muscle warm-up, the combination of interventions elicited the greatest improvement in running distance."[2]

Inspiratory muscle training can alter breathing mechanics, attenuate the oxygen cost, ventilation, HR, blood lactate, and the perceptual response during exercise and improve endurance exercise performance in recreational runners.

Twenty-four recreational road runners performed inspiratory flow resistive loading for six weeks. A significant improvement in endurance exercise capacity (+16.4%) during a treadmill run set at 80% VO2max occurred in this group versus no significant change in a control group.[3]

An external focus of attention is better than an internal focus in terms of the physiological performance measure of oxygen consumption during running.

"Trained runners had to focus their attention on three different aspects while running on a treadmill. For three consecutive 10-min periods, runners concentrated on the running movement, on their breathing, and on their surroundings. Results showed an increased running economy in the external focus condition."[4]

A study of collegiate cross-country runners showed that the combined analysis of a runner's VO2max and running economy could account for 92% of the variance in performance during an 8000-m race.

Running economy (efficiency) is expressed as the steady-state submaximal oxygen uptake at a given running velocity. The lower the oxygen consumption at a given submaximal running speed, the better the economy.[5]

Several modifiable factors exist that can improve running economy. Multiple factors also have conflicting or limited evidence concerning their effect on running economy.

"Improvements in [running economy (RE)] have ranged from 2 to 8 % using various short-term training modes, such as plyometric, strength and resistance, whole-body vibration, interval, altitude, and endurance running. In comparison, long-term physiological training can improve RE by 15 %."[6]

"There is an optimal stride length 'range' that trained runners can acutely adopt without compromising their RE. This range appears to be the preferred stride length minus 3 % to the preferred stride length… For novice runners, the difference between preferred and mathematically optimal stride frequencies is greater than for trained runners (8 vs. 3 %). Therefore, generalizing the principle of an optimal stride length range to all runners should be done with caution."[6]

Modifiable biomechanics and their effect on running economy:[6]
- Beneficial effect on running economy: self-selected stride length (minus 3%), low vertical oscillation, greater leg stiffness, less leg extension at toe-off, maintenance of arm swing, low muscle activation during propulsion, barefoot or lightweight shoes (< 440 g)
- Conflicting evidence for effect on running economy: ground contact time, swing time, impact force, trunk lean, orthotics
- Limited evidence for effect on running economy: horizontal distance between the foot and CoM at initial contact, foot-strike pattern

A 6-week core strength training program significantly increased 5000-m run times compared to controls (by 30 seconds).

The treatment performed 2-3 sets of 10-15 repetitions of the following exercises 4 times per week for 6 weeks: (1) abdominal crunch on a stability ball to target abdominal muscles, (2) back

extension on stability ball to target back extensor muscles, (3) supine opposite 1-arm/1-leg raise to target back/hip extensors muscles, (4) hip raise on stability ball to target back/hip extensors muscles, and (5) Russian twist on a stability ball to target abdominal muscles.[7]

"A Runner's Trunk and Respiration" References

1. Koplan JP, Powell KE, Sikes RK, Shirley RW, Campbell CC. An epidemiologic study of the benefits and risks of running. *JAMA*. 1982 Dec 17;248(23):3118-21.
2. Lomax M, Grant I, Corbett J. Inspiratory muscle warm-up and inspiratory muscle training: separate and combined effects on intermittent running to exhaustion. *J Sports Sci*. 2011 Mar;29(6):563-9.
3. Mickleborough TD, Nichols T, Lindley MR, Chatham K, Ionescu AA. Inspiratory flow resistive loading improves respiratory muscle function and endurance capacity in recreational runners. *Scand J Med Sci Sports*. 2010 Jun;20(3):458-68.
4. Schücker L, Hagemann N, Strauss B, Völker K. The effect of attentional focus on running economy. *J Sports Sci*. 2009 Oct;27(12):1241-8.
5. Lorenz DS, Reiman MP, Lehecka BJ, Naylor A. What Performance Characteristics Determine Elite Versus Nonelite Athletes in the Same Sport? *Sports Health*. 2013 Nov; 5(6): 542–547.
6. Moore IS. Is There an Economical Running Technique? A Review of Modifiable Biomechanical Factors Affecting Running Economy. *Sports Med*. 2016 Jun;46(6):793-807.
7. Sato K, Mokha M. Does core strength training influence running kinetics, lower-extremity stability, and 5000-M performance in runners? *J Strength Cond Res*. 2009 Jan;23(1):133-40.

Runners' Gluteals (B.J. Lehecka, DPT)

The gluteus maximus is arguably one of the most significant muscles of the human body. In addition to typically being the most massive muscle of the body, it has profound functional and athletic purposes. Gluteus maximus weakness has been linked to hip, knee, and ankle pathology.[1-3] A relationship exists between gluteus maximus strength and the performance of functional tasks including walking, stairs climbing, squatting, running, and jumping.[4,5] Additionally, gluteus maximus weakness has been correlated with abnormal lower extremity kinematics which may predispose individuals to injury.[6,7] The significant role of this muscle is evident among a wide spectrum of patients, from those undergoing hip replacement to active runners (especially female runners).[8,9] Females run with 40% greater peak gluteus maximus activation level and 53% greater average activation level than males.[9] (Willson, 2012)

Kang and colleagues studied activation of the gluteus maximus during prone hip extension with knee flexion in three positions of hip abduction.[10] Surface electromyography (EMG) signals were recorded for the gluteus maximus at 0°, 15°, and 30° of hip abduction. The results showed greatest gluteus maximus activity with the hip in 30° of abduction, followed by 15°, and then 0° where traditional muscle testing is performed. These results are logical given the laterally-oriented pennation angle of the gluteus maximus fibers. Although 0° of hip abduction is presumably easier to standardize, assessment of gluteus maximus strength (as distinct from hip extension strength) may be most valid in the abducted hip position.

Studies of gluteal exercises and EMG activity:

Boren K, Conrey C, Le Coguic J, Paprocki L, Voight M, Robinson TK. Electromyographic analysis of gluteus medius and gluteus maximus during rehabilitation exercises. *Int J Sports Phys Ther*. 2011 Sep;6(3):206-23.

Distefano LJ, Blackburn JT, Marshall SW, Padua DA. Gluteal muscle activation during common therapeutic exercises. *J Orthop Sports Phys Ther*. 2009 Jul;39(7):532-40.

Ekstrom RA, Donatelli RA, Carp KC. Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *J Orthop Sports Phys Ther*. 2007 Dec;37(12):754-62.

Reiman MP, Bolgla LA, Loudon JK. A literature review of studies evaluating gluteus maximus and gluteus medius activation during rehabilitation exercises. *Physiother Theory Pract*. 2012 May;28(4):257-68.

A case for gluteal endurance and gluteal endurance measures (GEMs):

Endurance is especially relevant to the gluteal muscles given their morphology. In one autopsy study, an estimated 58% of gluteus medius fibers were Type 1, the fiber type most suited for endurance activity.[11] Similarly, the gluteus maximus has been shown to be composed of 52-68% Type 1 fibers.[11,12] These significant proportions of Type I fibers demonstrate that the gluteals are suited for endurance activity. Both the gluteus medius and maximus contain moderate fiber sizes (neither small, nor large), which also demonstrates their substantial function for muscular endurance.[13]

The significance of gluteus medius endurance has been elucidated by multiple studies of low back pain and other pathology. For example, one study evidenced that a shorter endurance time during a side bridge exercise (an exercise requiring sustained, submaximal contraction of the gluteus medius) is suggestive of increased low back pain development during prolonged standing in healthy, young, individuals.[14] Similarly, clinical instructors with low back pain have demonstrated higher trunk and gluteus medius fatigue than asymptomatic individuals, demonstrated by reduced median frequency of the muscles during a 30-minute standing task.[15] A relationship has been found between side bridge endurance and low back pain.[16,17] Side bridge endurance, as a measure of gluteus medius function, is linked to various work-related musculoskeletal disorders,[18] static balance,[19] and peak internal rotation during running.[20]

The significance of gluteus maximus endurance is also evident in studies of low back pain. In a study of an isometric back extension endurance test, the gluteus maximus was the limiting factor for back extension endurance time in subjects with chronic low back pain.[21] In the chronic low back pain group, the gluteus maximus fatigued faster than in the control group. Research has shown a relationship between supine bridge endurance (an exercise requiring sustained, submaximal contraction of the gluteus maximus) and low back pain and disability in subjects with lumbar spondylolisthesis.[22-24] In these studies, lower endurance times are related to higher ratings of pain and disability.

"Runners' Gluteals" References

1. Grimaldi A, Richardson C, Durbridge G, Donnelly W, Darnell R, Hides J. The association between degenerative hip joint pathology and size of the gluteus maximus and tensor fascia lata muscles. *Man Ther*. 2009 Dec;14(6):611-7.
2. Rowe J, et al. Hip strength and knee pain in females. *N Am J Sports Phys Ther*. 2007 Aug;2(3):164-9.
3. Webster KA, Gribble PA. A comparison of electromyography of gluteus medius and maximus in subjects with and without chronic ankle instability during two functional exercises. *Phys Ther Sport*. 2013 Feb;14(1):17-22.
4. Long-Rossi F, Salsich GB. Pain and hip lateral rotator muscle strength contribute to functional status in females with patellofemoral pain. *Physiother Res Int*. 2010 Mar;15(1):57-64.
5. Lieberman DE, Raichlen DA, Pontzer H, Bramble DM, Cutright-Smith E. The human gluteus maximus and its role in running. *J Exp Biol*. 2006 Jun;209(Pt 11):2143-55.

6. Hollman JH, Hohl JM, Kraft JL, Strauss JD, Traver KJ. Hip extensor strength and gluteus maximus recruitment modulate frontal plane knee kinematics during a jump-landing task in healthy women. *J Sport Rehabil*. 2013 Apr 9.
7. Hollman JH, Ginos BE, Kozuchowski J, Vaughn AS, Krause DA, Youdas JW. Relationships between knee valgus, hip-muscle strength, and hip-muscle recruitment during a single-limb step-down. *J Sport Rehabil*. 2009 Feb;18(1):104-17.
8. Rasch A, Byström AH, Dalén N, Martinez-Carranza N, Berg HE. Persisting muscle atrophy two years after replacement of the hip. *J Bone Joint Surg Br*. 2009 May;91(5):583-8.
9. Willson JD, Petrowitz I, Butler RJ, Kernozek TW. Male and female gluteal muscle activity and lower extremity kinematics during running. *Clin Biomech (Bristol, Avon)*. 2012 Dec;27(10):1052-7.
10. Kang SY, Jeon HS, Kwon O, Cynn HS, Choi B. Activation of the gluteus maximus and hamstring muscles during prone hip extension with knee flexion in three hip abduction positions. *Man Ther*. 2013 Aug;18(4):303-7.
11. Širca Anton, Sušec-Michieli Majda. Selective type II fibre muscular atrophy in patients with osteoarthritis of the hip. *Journal of the Neurological Sciences*. 1980;44(2-3):149–159.
12. Johnson M, Polgar J, Weightman D, Appleton D. Data on the distribution of fibre types in thirty-six human muscles. *Journal of the Neurological Sciences*. 1973;18(1):111–129.
13. Ito J, Moriyama H, Inokuchi S, Goto N. Human Lower Limb Muscles: an Evaluation of Weight and Fiber Size. *Okajimas Folia Anatomica Japonica*. 2003;80(2.3):47–56.
14. Marshall PW, Patel H, Callaghan JP. Gluteus medius strength, endurance, and co-activation in the development of low back pain during prolonged standing. *Human Movement Science*. 2011;30(1):63–73.
15. Embaby E, Abdallah A. Trunk And Gluteus-Medius Muscles' Fatigability During Occupational Standing In Clinical Instructors With Low Back Pain. *British Journal of Sports Medicine*. 2013;47(10).
16. Correia JP, Oliveira R, Vaz JR, Silva L, Pezarat-Correia P. Trunk muscle activation, fatigue and low back pain in tennis players. *Journal of Science and Medicine in Sport*. 2016;19(4):311–316.
17. Swain C, Redding E. Trunk Muscle Endurance and Low Back Pain in Female Dance Students. *Journal of Dance Medicine & Science*. 2014;18(2):62–66.
18. Kurustien N, Mekhora K, Jalayondeja W, Nanthavanij S. Trunk Muscle Performance and Work-Related Musculoskeletal Disorders among Manual Lifting with Back Belt Wearing Workers. *Journal of the Medical Association of Thailand*. 2015;98 Suppl 5:S74-80.
19. Barati A, Safarcherati A, Aghayari A, Azizi F, Abbasi H. Evaluation of Relationship between Trunk Muscle Endurance and Static Balance in Male Students. *Asian Journal of Sports Medicine*. 2013;4(4).
20. Schmitz A, Russo K, Edwards L, Noehren B. Do novice runners have weak hips and bad running form? *Gait & Posture*. 2014;40(1):82–86.
21. Kankaanpää M, Taimela S, Laaksonen D, Hänninen O, Airaksinen O. Back and hip extensor fatigability in chronic low back pain patients and controls. *Archives of Physical Medicine and Rehabilitation*. 1998;79(4):412–417.
22. Schellenberg KL, Lang JM, Chan KM, Burnham RS. A Clinical Tool for Office Assessment of Lumbar Spine Stabilization Endurance. *American Journal of Physical Medicine & Rehabilitation*. 2007;86(5):380–386.
23. Ferrari S, Vanti C, O'reilly C. Clinical presentation and physiotherapy treatment of 4 patients with low back pain and isthmic spondylolisthesis. *Journal of Chiropractic Medicine*. 2012;11(2):94–103.
24. Ferrari S, Vanti C, Piccarreta R, Monticone M. Pain, Disability, and Diagnostic Accuracy of Clinical Instability and Endurance Tests in Subjects With Lumbar Spondylolisthesis. *Journal of Manipulative and Physiological Therapeutics*. 2014;37(9):647–659.

Running Related Injuries

Shaun O'Laughlin, PT, DPT, OCS

1. Running Related Lower Extremity Injuries
    a. Incidence
        i. 19.4%-79.3% (van Gent, 2007)
    b. Most Common Locations (Taunton et al, 2002; Taunton et al, 2003)
        i. Knee (Patellofemoral pain most common)
        ii. Foot/ankle
        iii. Lower leg
2. Contributing factors to running related injuries (Jones, 1999; Van Gent 2007)
    a. Intrinsic
        i. Age
        ii. Race
        iii. Gender
        iv. Prior Injury
    b. Extrinsic
        i. Training Parameters
        ii. Equipment
        iii. Terrain
        iv. Running Form
3. Running GAIT
    a. Foot Strike
        i. Rear foot strike
        ii. Non Rear foot strike
            1. Reduced patellofemoral loading
    b. Step Rate
        i. Increased step rate
            1. Reduced knee loading (Heiderscheit et al, 2011; Lenhart et al, 2014; Willy et al, 2016)
            2. Reduced breaking impulse (Hedierscheit et al, 2011)
            3. Reduces loading rate
            4. Reduces stride (distance of foot strike to center of mass)
4. Treatment Considerations for Running Injuries
    a. Training parameter considerations
    b. Running GAIT retraining
        i. While biomechanical studies provide rationale for run retraining, limited evidence exist in its effectiveness in patient populations
        ii. Chronic Exertional Compartment Syndrome
            1. Transition to forefoot strike with increased step rate resulted in reduced pain and increased function with running in surgical candidates with chronic exertional compartment syndrome (Diebal et al, 2012)
        iii. Patellofemoral Pain
            1. Transition to forefoot strike reduced loading rates and patellofemoral symptoms in female runners with patellofemoral pain (Cheung and Davis, 2011)
            2. Transition to a forefoot strike significantly reduced pain in subjects with patellofemoral pain compared to control group (Roper et al, 2016)

References:

Cheung RT, Davis IS. Landing pattern modification to improve patellofemoral pain in runners: a case series. *J Orthop Sports Phys Ther.* Dec 2011;41(12):914-919.

Daoud AI, Geissler GJ, Wang F, Saretsky J, Daoud YA, Lieberman DE. Foot strike and injury rates in endurance runners: a retrospective study. *Med Sci Sports Exerc.* Jul 2012;44(7):1325-1334.

Diebal AR, Gregory R, Alitz C, Gerber JP. Forefoot running improves pain and disability associated with chronic exertional compartment syndrome. *Am J Sports Med.* May 2012;40(5):1060-1067.

Jones BH, Knapik JJ. Physical training and exercise-related injuries. Surveillance, research and injury prevention in military populations. *Sports Med.* Feb 1999;27(2):111-125.

Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc.* Feb 2011;43(2):296-302.

Lenhart RL, Thelen DG, Wille CM, Chumanov ES, Heiderscheit BC. Increasing running step rate reduces patellofemoral joint forces. *Med Sci Sports Exerc.* Mar 2014;46(3):557-564.

Roper JL, Harding EM, Doerfler D, et al. The effects of gait retraining in runners with patellofemoral pain: A randomized trial. *Clin Biomech (Bristol, Avon).* Jun 2016;35:14-22.

Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med.* Apr 2002;36(2):95-101.

The Foot Influence

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I. Subtalar Joint
- A. Mechanics during running
  - Early stance: Pronation (7 – 8 degrees)
  - Late stance: Supination
- B. Faulty motion/intervention
  - Too much pronation
    - PFPS, MTSS (Barton, 2010; Williams et al., 2001)
    - Loss of talocrural dorsiflexion
      - Intervention: joint, muscle length
  - Too quick pronation
    - Excessive LE internal rotation
    - Hip control
    - Shoe – Rearfoot wedge
  - Too long pronation
    - Lose rigid lever for push-off
    - Forefoot varus
    - Hallux abducto valgus
    - Correction
      - Toe spread exercise
      - Short foot exercise
  - Lacking pronation
    - Increased rigidity – maldistribution of forces with increased wear of midfoot joint, plantar fascia, Achilles tendon, lateral ligaments
    - Intervention – joint, soft tissue

II. Midtarsal Joint (Midfoot)
- A. Calceneocuboid and Talonavicular Joints
- B. Mechanics during running
  - Calcaneal eversion: unlocks midtarsal joint
  - Calcaneal inversion locks midtarsal joint
- C. Faulty motion
  - Loss of foot control
  - Intervention
    - Intrinsic foot exercises (Doming, toe spreads)

III. Great toe
- A. Mechanism during running
  - Increase work of great toe decreases load on forefoot/midfoot (Mei et al.2015)
  - Great toe during heel off to allow Windlass mechanism
- B. Faulty motion
  - Hallux rigidus
  - Hallux abducto valgus

- Overpronation
- Heel raise exercise
- Taping

- Plantarflexed first ray

IV. Shoewear

A. Daily Shoewear

- High Heels
- Flip flops

B. Running Shoes

References

1. Barton CJ, Bonanno D, Levinger P, Menz HB. Foot and ankle characteristics in patellofemoral pain syndrome: a case control and reliability study. J Orthop Sports Phys Ther. 2010; 40(5): 286-296.
2. Bolgla LA, Malone TR, Umberger BR, Uhl TL. Hip strength and hip and knee kinematics during stair descent in females with and without patellofemoral pain syndrome. J Orthop Sports Phys Ther. 2008; 38(1): 12-18.
3. Deben SE, Pomeroy GC. Subtle cavus foot: Diagnosis and management. J Am Acad Orthop Surg. 2014; 22(8): 512-520.
4. Glasoe WM. Treatment of progressive first metatarsophalangeal hallux valgus deformity: A biomechanically based muscle-strengthening approach. J Orthop Sports Phys Ther. 2016; 46(7): 596-606.
5. Glasoe WM, Nuckley DJ, Ludewig PM. Hallux valgus and the first metatarsal arch segment: a theoretical biomechanical perspective. Phys Ther. 2010; 90(1): 110-120.
6. Macera C et al. Predicting lower extremity injuries among habitual runners. Arch Intern Med. 1989;149(11):2565-68.
7. Mei Q, GU Y, Ruan G. Foot function assessment through kinematic and kinetic analysis. 33rd International Conference on Biomechanics in Sports, 2015.
8. Powers CM. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. J Orthop Sports Phys Ther. 2003; 33(11): 639-646.
9. Sutlive et al. Identification of individuals with patellofemoral pain whose symptoms improved after a combined program of foot orthosis use and modified activity: a preliminary investigation. Phys Ther. 2004; 84(1):49 –61.
10. Taunton et al. A retrospective case-control analysis of 2002 running injuries. Br J Sports Med. 2002; 36(2):95-101.
11. Vicenzino B. Foot orthotics in the treatment of lower limb conditions: a musculoskeletal physiotherapy perspective. Man. Ther. 2004; 9(4):185-196.
12. Williams DS 3rd, McDlay IS, Hamill J. Arch structure and injury patterns in runners. Clin Biomech. 2001;16(4):341-7.
13. Willson JD, Davis IS. Lower extremity mechanics of females with and without patellofemoral pain across activities with progressively greater task demands. Clin Biomech. 2008;23(2):203-211.