2. Where is DNA located and what is its role?
3. What is the role of mitochondria in the cell?
4. What is the difference between aerobic and anaerobic metabolism?

BIBLIOGRAPHY

Ádám, V., Dux, L., Faragó, A., Fésüs, L., Machovich, R., Mandl, J., Sümegi, B., 2006. In: Ádám, V. (Ed.), Orvosi biokémia. Medicina Könyvkiadó Zrt., Budapest.
Fonyó, A., Hunyady, L., Kollai, M., Ligeti, E., Szűcs, G., 2003. Az orvosi élettan tankönyve. Medicina Könyvkiadó Zrt, Budapest.
Holloszy, J.O., 1967. Biochemical adaptations in muscle. Effects of exercise on mitochondrial oxygen uptake and respiratory enzyme activity in skeletal muscle. J. Biol. Chem. 242, 2278–2282.
Mooren, F., Volker, K. (Eds.), 2006. Molecular and Cellular Exercise Physiology. Human Kinetics, Champaign.
Radak, Z., Zhao, Z., Koltai, E., Ohno, H., Atalay, M., 2013. Oxygen consumption and usage during physical exercise: the balance between oxidative stress and ROS-dependent adaptive signaling. Antioxid. Redox Signal. 18, 1208–1246.
Sperelakis, N. (Ed.), 2001. Cell Physiology. Academic Press, San Diego.

limited by two Z-lines, which is the place of actin myofibrils attachment. During muscle contraction, Ca-ions are released from the sarcoplasmic reticulum and bind to troponin C, resulting in its conformation change. This leads to attachment of myosin and actin filaments, consumption of ATP, and consequential muscle shortening. Muscle contraction can be categorized as concentric, isometric, or eccentric, and the type of contraction determines the power that the muscle can generate. A single motor neuron and all the muscle fibers to which it connects is a motor unit; these units are categorized as type I red fibers, type IIa intermediate, and type IIb fast fibers based on their physiological properties. Muscle fibers can be categorized differently depending on their structural, metabolic, and stimulation properties.

TEST QUESTIONS

1. What are the main components of a myocyte?
2. What categories of muscle architecture can be established based on the arrangement of muscle fibers? What is the role of the arrangement of muscle fibers regarding the extent of muscle contraction?
3. What type of muscle contractions can be defined and what are their characteristics?
4. What is the mechanism of muscle contraction?
5. What is a motor unit?
6. What are the characteristics of fast, slow, and intermediate muscle fibers?

BIBLIOGRAPHY

Aagaard, P., Suetta, C., Caserotti, P., Magnusson, S.P., Kjaer, M., 2010. Role of the nervous system in sarcopenia and muscle atrophy with aging: strength training as a countermeasure. Scand. J. Med. Sci. Sports 20, 49–64.

Bosco, C., Tihanyi, J., Komi, P.V., Fekete, G., Apor, P., 1982. Store and recoil of elastic energy in slow and fast types of human skeletal muscles. Acta Physiol. Scand. 116, 343–349.

Glass, D.J., 2010. Signaling pathways perturbing muscle mass. Curr. Opin. Clin. Nutr. Metab. Care 13, 225–229.

Hill, E.W., Gu, J., Eivers, S.S., Fonseca, R.G., McGivney, B.A., Govindarajan, P., Orr, N., Katz, L.M., MacHugh, D.E., 2010. A sequence polymorphism in MSTN predicts sprinting ability and racing stamina in thoroughbred horses. PLoS One 5, e8645.

Hortobagyi, T., Houmard, J.A., Stevenson, J.R., Fraser, D.D., Johns, R.A., Israel, R.G., 1993. The effects of detraining on power athletes. Med. Sci. Sports Exerc. 25, 929–935.

Kimball, S.R., Jefferson, L.S., 2010. Control of translation initiation through integration of signals generated by hormones, nutrients, and exercise. J. Biol. Chem. 285, 29027–29032.

Linklater, J.M., Hamilton, B., Carmichael, J., Orchard, J., Wood, D.G., 2010. Hamstring injuries: anatomy, imaging, and intervention. Semin. Musculoskelet. Radiol. 14, 131–161.

Malisoux, L., Francaux, M., Theisen, D., 2007. What do single-fiber studies tell us about exercise training? Med. Sci. Sports Exerc. 39, 1051–1060.

Moyes, C.D., LeMoine, C.M., 2005. Control of muscle bioenergetic gene expression: implications for allometric scaling relationships of glycolytic and oxidative enzymes. J. Exp. Biol. 208, 1601–1610.
Olesen, J., Kiilerich, K., Pilegaard, H., 2010. PGC-1alpha-mediated adaptations in skeletal muscle. Pflugers Arch.: Eur. J. Physiol. 460, 153–162.
Radak, Z., Chung, H.Y., Goto, S., 2008. Systemic adaptation to oxidative challenge induced by regular exercise. Free Radic. Biol. Med. 44, 153–159.
Sargeant, A.J., 2007. Structural and functional determinants of human muscle power. Exp. Physiol. 92, 323–331.
Schiaffino, S., Sandri, M., Murgia, M., 2007. Activity-dependent signaling pathways controlling muscle diversity and plasticity. Physiology 22, 269–278.
Sun, Z., Liu, L., Liu, N., Liu, Y., 2008. Muscular response and adaptation to diabetes mellitus. Front. Biosci. J.Virtual Libr. 13, 4765–4794.
Tee, J.C., Bosch, A.N., Lambert, M.I., 2007. Metabolic consequences of exercise-induced muscle damage. Sports Med. 37, 827–836.

microscopic injuries and results in pain. Overtraining is a complex process determined by multiple factors, which may result in long-lasting underperformance. Symptoms of overtraining can be divided into physiological, biochemical, immunological, and psychological groups.

TEST QUESTIONS

1. How do homeostasis and adaptation correlate?
2. What are the main types and characteristics of adaptation?
3. What are the causes of central and peripheral fatigue?
4. What are the characteristics of muscle fever?
5. What are the symptoms of overtraining?
6. What opportunities does a trainer have to prevent overtraining and to enhance regeneration?

BIBLIOGRAPHY

Borresen, J., Lambert, M.I., 2009. The quantification of training load, the training response and the effect on performance. Sports Med. 39, 779–795.

Davies, D.J., Graham, K.S., Chow, C.M., 2010. The effect of prior endurance training on nap sleep patterns. Int. J. Sports Physiol. Perform. 5, 87–97.

Flueck, M., 2009. Plasticity of the muscle proteome to exercise at altitude. High Alt. Med. Biol. 10, 183–193.

Issurin, V.B., 2010. New horizons for the methodology and physiology of training periodization. Sports Med. 40, 189–206.

Kjaer, M., Langberg, H., Heinemeier, K., Bayer, M.L., Hansen, M., Holm, L., Doessing, S., Kongsgaard, M., Krogsgaard, M.R., Magnusson, S.P., 2009. From mechanical loading to collagen synthesis, structural changes and function in human tendon. Scand. J. Med. Sci. Sports 19, 500–510.

Lundby, C., Calbet, J.A., Robach, P., 2009. The response of human skeletal muscle tissue to hypoxia. Cell. Mol. Life Sci. 66, 3615–3623.

Morton, J.P., Kayani, A.C., McArdle, A., Drust, B., 2009. The exercise-induced stress response of skeletal muscle, with specific emphasis on humans. Sports Med. 39, 643–662.

Murase, S., Terazawa, E., Queme, F., Ota, H., Matsuda, T., Hirate, K., Kozaki, Y., Katanosaka, K., Taguchi, T., Urai, H., Mizumura, K., 2010. Bradykinin and nerve growth factor play pivotal roles in muscular mechanical hyperalgesia after exercise (delayed-onset muscle soreness). J. Neurosci. 30, 3752–3761.

Murton, A.J., Greenhaff, P.L., 2010. Physiological control of muscle mass in humans during resistance exercise, disuse and rehabilitation. Curr. Opin. Clin. Nutr. Metab. Care 13, 249–254.

Radak, Z., Chung, H.Y., Koltai, E., Taylor, A.W., Goto, S., 2008. Exercise, oxidative stress and hormesis. Ageing Res. Rev. 7, 34–42.

Reid, K.J., Baron, K.G., Lu, B., Naylor, E., Wolfe, L., Zee, P.C., 2010. Aerobic exercise improves self-reported sleep and quality of life in older adults with insomnia. Sleep Med. 11, 934–940.

TEST QUESTIONS

1. What factors determine the force generated by the muscle?
2. What is the mechanism of cross-sectional area growth of muscles?
3. How are motor units recruited during different loading?
4. Explain the correlation between different types of muscle contractions and the force generated by the muscle.
5. What are the characteristics of the maximal strength training method?
6. What are the differences between the maximal strength and speed strength training methods?
7. What are the most important factors in strength endurance development?
8. What is the difference between neuromuscular coordination training and training for cross-sectional area growth?
9. Why and how does age affect adaptation to strength training?

BIBLIOGRAPHY

Bruusgaard, J.C., Johansen, I.B., Egner, I.M., Rana, Z.A., Gundersen, K., 2010. Myonuclei acquired by overload exercise precede hypertrophy and are not lost on detraining. Proc. Natl. Acad. Sci. U. S. A. 107, 15111–15116.

Cloak, R., Nevill, A., Day, S., Wyon, M., 2013. Six-week combined vibration and wobble board training on balance and stability in footballers with functional ankle instability. Clin. J. Sport Med. 23, 384–391.

Collier, S.R., Casey, D.P., Kanaley, J.A., 2005. Growth hormone responses to varying doses of oral arginine. Growth Horm. IGF Res. 15, 136–139.

D'Antona, G., Lanfranconi, F., Pellegrino, M.A., Brocca, L., Adami, R., Rossi, R., Moro, G., Miotti, D., Canepari, M., Bottinelli, R., 2006. Skeletal muscle hypertrophy and structure and function of skeletal muscle fibres in male body builders. J. Physiol. 570, 611–627.

Duchateau, J., Semmler, J.G., Enoka, R.M., 2006. Training adaptations in the behavior of human motor units. J. Appl. Physiol. 101, 1766–1775.

Fling, B.W., Christie, A., Kamen, G., 2009. Motor unit synchronization in FDI and biceps brachii muscles of strength-trained males. J. Electromyogr. Kinesiol. 19, 800–809.

Frystyk, J., 2010. Exercise and the growth hormone-insulin-like growth factor axis. Med. Sci. Sports Exerc. 42, 58–66.

Hackney, A.C., 2001. Endurance exercise training and reproductive endocrine dysfunction in men: alterations in the hypothalamic-pituitary-testicular axis. Curr. Pharm. Des. 7, 261–273.

Hakkinen, K., 1994. Neuromuscular fatigue in males and females during strenuous heavy resistance loading. Electromyogr. Clin. Neurophysiol. 34, 205–214.

Herrmann, U., Flanders, M., 1998. Directional tuning of single motor units. J. Neurosci. 18, 8402–8416.

Item, F., Nocito, A., Thony, S., Bachler, T., Boutellier, U., Wenger, R.H., Toigo, M., 2013. Combined whole-body vibration, resistance exercise, and sustained vascular occlusion increases PGC-1alpha and VEGF mRNA abundances. Eur. J. Appl. Physiol. 113, 1081–1090.

Kostka, T., Patricot, M.C., Mathian, B., Lacour, J.R., Bonnefoy, M., 2003. Anabolic and catabolic hormonal responses to experimental two-set low-volume resistance exercise in sedentary and active elderly people. Aging Clin. Exp. Res. 15, 123–130.

Langley, B., Thomas, M., Bishop, A., Sharma, M., Gilmour, S., Kambadur, R., 2002. Myostatin inhibits myoblast differentiation by down-regulating MyoD expression. J. Biol. Chem. 277, 49831–49840.

Lu, H., Huang, D., Saederup, N., Charo, I.F., Ransohoff, R.M., Zhou, L., 2011. Macrophages recruited via CCR2 produce insulin-like growth factor-1 to repair acute skeletal muscle injury. FASEB J. 25, 358–369.

Maejima, H., Murase, A., Sunahori, H., Kanetada, Y., Otani, T., Yoshimura, O., Tobimatsu, Y., 2007. Neural adjustment in the activation of the lower leg muscles through daily physical exercises in community-based elderly persons. Tohoku J. Exp. Med. 211, 141–149.

Martineau, L.C., Gardiner, P.F., 2001. Insight into skeletal muscle mechanotransduction: MAPK activation is quantitatively related to tension. J. Appl. Physiol. 91, 693–702.

McDonagh, J.C., Binder, M.D., Reinking, R.M., Stuart, D.G., 1980. A commentary on muscle unit properties in cat hindlimb muscles. J. Morphol. 166, 217–230.

McDonald, K.S., Wolff, M.R., Moss, R.L., 1997. Sarcomere length dependence of the rate of tension redevelopment and submaximal tension in rat and rabbit skinned skeletal muscle fibres. J. Physiol. 501 (Pt 3), 607–621.

Nishida, Y., Matsubara, T., Tobina, T., Shindo, M., Tokuyama, K., Tanaka, K., Tanaka, H., 2010. Effect of low-intensity aerobic exercise on insulin-like growth factor-I and insulin-like growth factor-binding proteins in healthy men. Int. J. Endocrinol. 2010.

Ogasawara, R., Kobayashi, K., Tsutaki, A., Lee, K., Abe, T., Fujita, S., Nakazato, K., Ishii, N., 2013. mTOR signaling response to resistance exercise is altered by chronic resistance training and detraining in skeletal muscle. J. Appl. Physiol. 114, 934–940.

Perry, R.L., Rudnick, M.A., 2000. Molecular mechanisms regulating myogenic determination and differentiation. Front. Biosci. 5, D750–767.

Pette, D., Smith, M.E., Staudte, H.W., Vrbova, G., 1973. Effects of long-term electrical stimulation on some contractile and metabolic characteristics of fast rabbit muscles. Pflugers Archiv: Eur. J. Physiol. 338, 257–272.

Snarr, R.L., Esco, M.R., 2013. Electromyographic comparison of traditional and suspension push-ups. J. Human Kinetics 39, 75–83.

Sparkes, R., Behm, D.G., 2010. Training adaptations associated with an 8-week instability resistance training program with recreationally active individuals. J. Strength Cond. Res. 24, 1931–1941.

Verhagen, E., van der Beek, A., Twisk, J., Bouter, L., Bahr, R., van Mechelen, W., 2004. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. Am. J. Sports Med. 32, 1385–1393.

Vingren, J.L., Kraemer, W.J., Ratamess, N.A., Anderson, J.M., Volek, J.S., Maresh, C.M., 2010. Testosterone physiology in resistance exercise and training: the up-stream regulatory elements. Sports Med. 40, 1037–1053.

Wernbom, M., Augustsson, J., Thomee, R., 2007. The influence of frequency, intensity, volume and mode of strength training on whole muscle cross-sectional area in humans. Sports Med. 37, 225–264.

West, D.W., Phillips, S.M., 2010. Anabolic processes in human skeletal muscle: restoring the identities of growth hormone and testosterone. Phys. Sportsmed. 38, 97–104.

Zajac, F.E., Faden, J.S., 1985. Relationship among recruitment order, axonal conduction velocity, and muscle-unit properties of type-identified motor units in cat plantaris muscle. J. Neurophysiol. 53, 1303–1322.

4. What is the anaerobic threshold, and what is its importance in endurance training?
5. What are the characteristics of adaptation to endurance training?
6. What training methods are efficient to improve heart functions and how do they work?
7. What training methods would you recommend to improve oxidative functions of mitochondria in skeletal muscles?
8. How would you improve resistance to lactic acid and how does it work?
9. What type of endurance training would you recommend a football player and a 1 min. Swimmer?
10. Why is high-altitude training not always useful to improve endurance?
11. What type of training would you recommend to improve health and how does it work?

BIBLIOGRAPHY

Baggish, A.L., Wang, F., Weiner, R.B., Elinoff, J.M., Tournoux, F., Boland, A., Picard, M.H., Hutter Jr., A.M., Wood, M.J., 2008. Training-specific changes in cardiac structure and function: a prospective and longitudinal assessment of competitive athletes. J. Appl. Physiol. 104, 1121–1128.

Bangsbo, J., Michalsik, L., Petersen, A., 1993. Accumulated O_2 deficit during intense exercise and muscle characteristics of elite athletes. Int. J. Sports Med. 14, 207–213.

Bangsbo, J., Iaia, F.M., Krustrup, P., 2007. Metabolic response and fatigue in soccer. Int. J. Sports Physiol. Perform. 2, 111–127.

Barnes, B.R., Glund, S., Long, Y.C., Hjalm, G., Andersson, L., Zierath, J.R., 2005. 5′-AMP-activated protein kinase regulates skeletal muscle glycogen content and ergogenics. FASEB J. 19, 773–779.

Bassett Jr., D.R., Howley, E.T., 2000. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med. Sci. Sports Exerc. 32, 70–84.

Bosquet, L., Leger, L., Legros, P., 2002. Methods to determine aerobic endurance. Sports Med. 32, 675–700.

Bouchard, C., Lesage, R., Lortie, G., Simoneau, J.A., Hamel, P., Boulay, M.R., Perusse, L., Theriault, G., Leblanc, C., 1986. Aerobic performance in brothers, dizygotic and monozygotic twins. Med. Sci. Sports Exerc. 18, 639–646.

Brooks, G.A., 1986. Lactate production under fully aerobic conditions: the lactate shuttle during rest and exercise. Fed. Proc. 45, 2924–2929.

Brosnan, M.J., Martin, D.T., Hahn, A.G., Gore, C.J., Hawley, J.A., 2000. Impaired interval exercise responses in elite female cyclists at moderate simulated altitude. J. Appl. Physiol. 89, 1819–1824.

Chi, M.M., Hintz, C.S., Coyle, E.F., Martin 3rd, W.H., Ivy, J.L., Nemeth, P.M., Holloszy, J.O., Lowry, O.H., 1983. Effects of detraining on enzymes of energy metabolism in individual human muscle fibers. Am. J. Phys. 244, C276–C287.

Costill, D.L., Thomason, H., Roberts, E., 1973. Fractional utilization of the aerobic capacity during distance running. Med. Sci. Sports 5, 248–252.

Coyle, E.F., Feltner, M.E., Kautz, S.A., Hamilton, M.T., Montain, S.J., Baylor, A.M., Abraham, L.D., Petrek, G.W., 1991. Physiological and biomechanical factors associated with elite endurance cycling performance. Med. Sci. Sports Exerc. 23, 93–107.

Coyle, E.F., 1995. Integration of the physiological factors determining endurance performance ability. Exerc. Sport Sci. Rev. 23, 25–63.
Czuba, M., Maszczyk, A., Gerasimuk, D., Roczniok, R., Fidos-Czuba, O., Zajac, A., Golas, A., Mostowik, A., Langfort, J., 2014. The effects of hypobaric hypoxia on erythropoiesis, maximal oxygen uptake and energy cost of exercise under normoxia in elite biathletes. J. Sports Sci. Med. 13, 912–920.
Dosek, A., Ohno, H., Acs, Z., Taylor, A.W., Radak, Z., 2007. High altitude and oxidative stress. Respir. Physiol. Neurobiol. 158, 128–131.
Duncker, D.J., Bache, R.J., 2008. Regulation of coronary blood flow during exercise. Physiol. Rev. 88, 1009–1086.
Durakovic, Z., Misigoj-Durakovic, M., Medved, R., Skavic, J., Torovic, N., 2002. Sudden death due to physical exercise in the elderly. Coll. Antropol. 26, 239–243.
Forbes, S.C., Paganini, A.T., Slade, J.M., Towse, T.F., Meyer, R.A., 2009. Phosphocreatine recovery kinetics following low- and high-intensity exercise in human triceps surae and rat posterior hindlimb muscles. Am. J. Physiol. Regul. Integr. Comp. Physiol. 296, R161–170.
Gibala, M.J., McGee, S.L., Garnham, A.P., Howlett, K.F., Snow, R.J., Hargreaves, M., 2009. Brief intense interval exercise activates AMPK and p38 MAPK signaling and increases the expression of PGC-1alpha in human skeletal muscle. J. Appl. Physiol. 106, 929–934.
Gollnick, P.D., Armstrong, R.B., Saubert, C.W., Sembrowich, W.L., Shepherd, R.E., Saltin, B., 1973. Glycogen depletion patterns in human skeletal muscle fibers during prolonged work. Pflugers Arch. 344, 1–12.
Hamel, P., Simoneau, J.A., Lortie, G., Boulay, M.R., Bouchard, C., 1986. Heredity and muscle adaptation to endurance training. Med. Sci. Sports Exerc. 18, 690–696.
Henriksson, J., Reitman, J.S., 1976. Quantitative measures of enzyme activities in type I and type II muscle fibres of man after training. Acta Physiol. Scand. 97, 392–397.
Hill, A.V., Lupton, H., 1923. Muscular exercise, lactic acid, and the supply and utilization of oxygen. QJM 16, 135–171.
Holloszy, J.O., Coyle, E.F., 1984. Adaptations of skeletal muscle to endurance exercise and their metabolic consequences. J. Appl. Physiol. Respir. Environ. Exerc. Physiol. 56, 831–838.
Hood, D.A., Terjung, R.L., 1990. Amino acid metabolism during exercise and following endurance training. Sports Med. 9, 23–35.
Jeukendrup, A.E., 2002. Regulation of fat metabolism in skeletal muscle. Ann. N.Y. Acad. Sci. 967, 217–235.
Jeukendrup, A.E., 2003. Modulation of carbohydrate and fat utilization by diet, exercise and environment. Biochem. Soc. Trans. 31, 1270–1273.
Jones, A.M., Doust, J.H., 1998. The validity of the lactate minimum test for determination of the maximal lactate steady state. Med. Sci. Sports Exerc. 30, 1304–1313.
Kindermann, W., Simon, G., Keul, J., 1979. The significance of the aerobic-anaerobic transition for the determination of work load intensities during endurance training. Eur. J. Appl. Physiol. Occup. Physiol. 42, 25–34.
Larsen, R.G., Befroy, D.E., Kent-Braun, J.A., 2013. High-intensity interval training increases in vivo oxidative capacity with no effect on P(i)→ATP rate in resting human muscle. Am. J. Physiol. Regul. Integr. Comp. Physiol. 304, R333–342.
Lauschke, J., Maisch, B., 2009. Athlete's heart or hypertrophic cardiomyopathy? Clin. Res. Cardiol. 98, 80–88.
Marliss, E.B., Vranic, M., 2002. Intense exercise has unique effects on both insulin release and its roles in glucoregulation: implications for diabetes. Diabetes 51 (Suppl 1), S271–283.
Millet, G.P., Roels, B., Schmitt, L., Woorons, X., Richalet, J.P., 2010. Combining hypoxic methods for peak performance. Sports Med. 40, 1–25.

Noordhof, D.A., de Koning, J.J., Foster, C., 2010. The maximal accumulated oxygen deficit method: a valid and reliable measure of anaerobic capacity? Sports Med. 40, 285–302.

Pilarski, J.Q., Solomon, I.C., Kilgore Jr., D.L., Hempleman, S.C., 2009. Effects of aerobic and anaerobic metabolic inhibitors on avian intrapulmonary chemoreceptors. Am. J. Physiol. Regul. Integr. Comp. Physiol. 296, R1576–1584.

Pluim, B.M., Zwinderman, A.H., van der Laarse, A., van der Wall, E.E., 2000. The athlete's heart. A meta-analysis of cardiac structure and function. Circulation 101, 336–344.

Richter, E.A., Kiens, B., Saltin, B., Christensen, N.J., Savard, G., 1988. Skeletal muscle glucose uptake during dynamic exercise in humans: role of muscle mass. Am. J. Phys. 254, E555–561.

Robach, P., Bonne, T., Fluck, D., Burgi, S., Toigo, M., Jacobs, R.A., Lundby, C., 2014. Hypoxic training: effect on mitochondrial function and aerobic performance in hypoxia. Med. Sci. Sports Exerc. 46, 1936–1945.

Sloth, M., Sloth, D., Overgaard, K., Dalgas, U., 2013. Effects of sprint interval training on VO_{2max} and aerobic exercise performance: a systematic review and meta-analysis. Scand. J. Med. Sci. Sports 23, e341–352.

Tadaishi, M., Miura, S., Kai, Y., Kawasaki, E., Koshinaka, K., Kawanaka, K., Nagata, J., Oishi, Y., Ezaki, O., 2011. Effect of exercise intensity and AICAR on isoform-specific expressions of murine skeletal muscle PGC-1alpha mRNA: a role of beta(2)-adrenergic receptor activation. Am. J. Phys. Endocrinol. Metab. 300, E341–349.

Tanaka, H., Seals, D.R., 2008. Endurance exercise performance in masters athletes: age-associated changes and underlying physiological mechanisms. J. Physiol. 586, 55–63.

Timmons, J.A., 2011. Variability in training-induced skeletal muscle adaptation. J. Appl. Physiol. 110, 846–853.

Turcotte, L.P., 2000. Muscle fatty acid uptake during exercise: possible mechanisms. Exerc. Sport Sci. Rev. 28, 4–9.

Weston, M., Taylor, K.L., Batterham, A.M., Hopkins, W.G., 2014. Effects of low-volume high-intensity interval training (HIT) on fitness in adults: a meta-analysis of controlled and non-controlled trials. Sports Med. 44, 1005–1017.

Yoshida, T., 1984. Effect of dietary modifications on lactate threshold and onset of blood lactate accumulation during incremental exercise. Eur. J. Appl. Physiol. Occup. Physiol. 53, 200–205.

TEST QUESTIONS

(1) What factors determine speed?
(2) What exercises can improve speed?
(3) What elements is speed comprised of?
(4) What are the main characteristics of fast-twitch muscle fibers?
(5) What is a speed limiting factor?

BIBLIOGRAPHY

Ahmed, O.J., Mehta, M.R., 2012. Running speed alters the frequency of hippocampal gamma oscillations. J. Neurosci. 32, 7373–7383.
Braddick, O., Atkinson, J., 2007. Development of brain mechanisms for visual global processing and object segmentation. Prog. Brain Res. 164, 151–168.
Buchheit, M., Laursen, P.B., 2013. High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. Sports Med. 43, 927–954.
Buzsaki, G., 2005. Theta rhythm of navigation: link between path integration and landmark navigation, episodic and semantic memory. Hippocampus 15, 827–840.
Cummins, C., Orr, R., O'Connor, H., West, C., 2013. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. Sports Med. 43, 1025–1042.
Diba, K., Buzsaki, G., 2008. Hippocampal network dynamics constrain the time lag between pyramidal cells across modified environments. J. Neurosci. 28, 13448–13456.
Grissmer, D., Grimm, K.J., Aiyer, S.M., Murrah, W.M., Steele, J.S., 2010. Fine motor skills and early comprehension of the world: two new school readiness indicators. Dev. Psychol. 46, 1008–1017.
Lockie, R.G., Murphy, A.J., Knight, T.J., Janse de Jonge, X.A., 2011. Factors that differentiate acceleration ability in field sport athletes. J. Strength Cond. Res. 25, 2704–2714.
Martin, C., Thevenet, D., Zouhal, H., Mornet, Y., Deles, R., Crestel, T., Ben Abderrahman, A., Prioux, J., 2011. Effects of playing surface (hard and clay courts) on heart rate and blood lactate during tennis matches played by high-level players. J. Strength Cond. Res. 25, 163–170.
McNaughton, B.L., Barnes, C.A., O'Keefe, J., 1983. The contributions of position, direction, and velocity to single unit activity in the hippocampus of freely-moving rats. Exp. Brain Res. 52, 41–49.
Montgomery, S.M., Buzsaki, G., 2007. Gamma oscillations dynamically couple hippocampal CA3 and CA1 regions during memory task performance. Proc. Natl. Acad. Sci. U. S. A. 104, 14495–14500.
Takeuchi, N., Oouchida, Y., Izumi, S., 2012. Motor control and neural plasticity through interhemispheric interactions. Neural Plast. 2012, 823285.

7.5 "R" EXTRA

Six-seven strength training followed by stretching significantly improved the speed of serving of young tennis players, and decreased the risk of injuries compared to a group participating only in strength training (Fernandez-Fernandez et al., 2013). The combined training widened the range of movements, so they could accelerate the tennis racket over a longer distance and hit the ball with a higher velocity. Thus, increasing the range of movements has a positive effect in tennis according to those authors.

Regeneration with cold and hot water baths is a generally used method following training; however, measurements did not indicate increased stretchiness of the thigh flexors (Burke et al., 2001). Selection of optimal flexibility training depends on the type of sport, and this ability also needs to be monitored frequently.

7.6 SUMMARY

Joint flexibility is strongly correlated with performance in certain sports. Every sport requires some degree of joint flexibility, and some need a high degree of flexibility. During flexibility training, the myotatic (stretch) reflex needs to be considered since its switching off through different stretching methods is an important element in flexibility development.

TEST QUESTIONS

(1) What determines range of motion?
(2) What role does the Golgi tendon organ have?
(3) What is the physiological base of stretching?
(4) What is PNF?
(5) What is the correlation between flexibility and strength?
(6) Why is joint flexibility important?

BIBLIOGRAPHY

Allen, D.J., 2014. Treatment of distal iliotibial band syndrome in a long distance runner with gait re-training emphasizing step rate manipulation. Int. J. Sports Phys. Ther. 9, 222–231.

Behm, D.G., Chaouachi, A., 2011. A review of the acute effects of static and dynamic stretching on performance. Eur. J. Appl. Physiol. 111, 2633–2651.

Bien, D.P., 2011. Rationale and implementation of anterior cruciate ligament injury prevention warm-up programs in female athletes. J. Strength Cond. Res. 25, 271–285.

Burke, D.G., Holt, L.E., Rasmussen, R., MacKinnon, N.C., Vossen, J.F., Pelham, T.W., 2001. Effects of hot or cold water immersion and modified proprioceptive neuromuscular facilitation flexibility exercise on hamstring length. J. Athl. Train. 36, 16–19.

Fernandez-Fernandez, J., Ellenbecker, T., Sanz-Rivas, D., Ulbricht, A., Ferrautia, A., 2013. Effects of a 6-week junior tennis conditioning program on service velocity. J. Sports Sci. Med. 12, 232–239.

Goldman, E.F., Jones, D.E., 2010. Interventions for preventing hamstring injuries. Cochrane Database Syst. Rev. (1) CD006782. https://doi.org/10.1002/14651858.CD006782.pub2.

Jenkins, J., Beazell, J., 2010. Flexibility for runners. Clin. Sports Med. 29, 365–377.

Kallerud, H., Gleeson, N., 2013. Effects of stretching on performances involving stretch-shortening cycles. Sports Med. 43, 733–750.

Lauersen, J.B., Bertelsen, D.M., Andersen, L.B., 2014. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. Br. J. Sports Med. 48, 871–877.

Liederbach, M., 2010. Perspectives on dance science rehabilitation understanding whole body mechanics and four key principles of motor control as a basis for healthy movement. J. Dance Med. Sci. 14, 114–124.

McHugh, M.P., Cosgrave, C.H., 2010. To stretch or not to stretch: the role of stretching in injury prevention and performance. Scand. J. Med. Sci. Sports 20, 169–181.

Weldon, S.M., Hill, R.H., 2003. The efficacy of stretching for prevention of exercise-related injury: a systematic review of the literature. Man. Ther. 8, 141–150.

Winters, M., Eskes, M., Weir, A., Moen, M.H., Backx, F.J., Bakker, E.W., 2013. Treatment of medial tibial stress syndrome: a systematic review. Sports Med. 43, 1315–1333.

Yamaguchi, T., Ishii, K., Yamanaka, M., Yasuda, K., 2007. Acute effects of dynamic stretching exercise on power output during concentric dynamic constant external resistance leg extension. J. Strength Cond. Res. 21, 1238–1244.

Timing of nutritional intervention is crucial and aims to enhance performance, delay fatigue, and enhance regeneration. The type of nutritional intervention should depend on the intensity and the duration of exercise. Prolonged exercise with an intensity of VO_2max 60%–80% with duration longer than 60 min. Relies on carbohydrate metabolism and availability; therefore carbohydrate loading before and during exercise improves performance. Rapid ingestion of carbohydrates >1.2 g/kg/h for 4–6 h after heavy exercise loads rapidly stimulates regeneration of muscle glycogen, especially when 0.2–0.5 g/kg/h protein is added to carbohydrate (Kerksick et al., 2017). Taking proteins before and even during training, which aims to increase muscle hypertrophy, provides enhanced muscle protein synthesis, which can also be increased by 30–40 g of casein intake 30 min. Before sleeping (Kerksick et al., 2017).

8.7 SUMMARY

A well-designed diet during a training period provides an optimal level of nutrition available during the competition. During a race, liquid and nutrition intake delay the development of fatigue and improve performance. Furthermore, we can improve the buffer capacity of the body, which improves performance in endurance sports. A balanced diet before and after training promotes the regeneration process. In weight-class sports, a well-designed diet is extremely important with continuous control during preparation, and quick weight loss should be avoided.

TEST QUESTIONS

1. How does diet determine the glycogen content of muscle?
2. What nutrition facilitates the buildup of glycogen following training?
3. What effects does caffeine have on performance?
4. What nutrition is recommended for muscle growth?
5. What nutrition is recommended during aerobic endurance training?
6. What sports gain benefits from creatine monohydrate intake, and why?
7. What is the best method to control weight in weight-class sports?

BIBLIOGRAPHY

Baguet, A., Koppo, K., Pottier, A., Derave, W., 2010. Beta-alanine supplementation reduces acidosis but not oxygen uptake response during high-intensity cycling exercise. Eur. J. Appl. Physiol. 108, 495–503.

Beard, J., Tobin, B., 2000. Iron status and exercise. Am. J. Clin. Nutr. 72, 594S–597S.

Bergstrom, J., Hermansen, L., Hultman, E., Saltin, B., 1967. Diet, muscle glycogen and physical performance. Acta Physiol. Scand. 71, 140–150.
Berkulo, M.A., Bol, S., Levels, K., Lamberts, R.P., Daanen, H.A., Noakes, T.D., 2015. Ad-libitum drinking and performance during a 40-km cycling time trial in the heat. Eur. J. Sport Sci, 1–8.
Burke, L.M., Collier, G.R., Hargreaves, M., 1993. Muscle glycogen storage after prolonged exercise: effect of the glycemic index of carbohydrate feedings. J. Appl. Physiol. 75, 1019–1023.
Casey, A., Mann, R., Banister, K., Fox, J., Morris, P.G., Macdonald, I.A., Greenhaff, P.L., 2000. Effect of carbohydrate ingestion on glycogen resynthesis in human liver and skeletal muscle, measured by (13)C MRS. Am. J. Phys. Endocrinol. Metab. 278, E65–75.
Chua, M., Baldwin, T.C., Hocking, T.J., Chan, K., 2010. Traditional uses and potential health benefits of *Amorphophallus konjac* K. Koch ex N.E.Br. J. Ethnopharmacol. 128, 268–278.
Cox, G.R., Desbrow, B., Montgomery, P.G., Anderson, M.E., Bruce, C.R., Macrides, T.A., Martin, D.T., Moquin, A., Roberts, A., Hawley, J.A., Burke, L.M., 2002. Effect of different protocols of caffeine intake on metabolism and endurance performance. J. Appl. Physiol. 93, 990–999.
Decombaz, J., Fleith, M., Hoppeler, H., Kreis, R., Boesch, C., 2000. Effect of diet on the replenishment of intramyocellular lipids after exercise. Eur. J. Nutr. 39, 244–247.
Floyd Jr., J.C., Fajans, S.S., Conn, J.W., Knopf, R.F., Rull, J., 1966. Insulin secretion in response to protein ingestion. J. Clin. Invest. 45, 1479–1486.
Giles, G.E., Mahoney, C.R., Kanarek, R.B., 2013. Omega-3 fatty acids influence mood in healthy and depressed individuals. Nutr. Rev. 71, 727–741.
Girgis, C.M., Clifton-Bligh, R.J., Hamrick, M.W., Holick, M.F., Gunton, J.E., 2013. The roles of vitamin D in skeletal muscle: form, function, and metabolism. Endocr. Rev. 34, 33–83.
Golf, S.W., Happel, O., Graef, V., Seim, K.E., 1984. Plasma aldosterone, cortisol and electrolyte concentrations in physical exercise after magnesium supplementation. J. Clin. Chem. Clin. Biochem. Zeitschrift fur klinische Chemie und klinische Biochemie 22, 717–721.
Gomez-Pinilla, F., Ying, Z., 2010. Differential effects of exercise and dietary docosahexaenoic acid on molecular systems associated with control of allostasis in the hypothalamus and hippocampus. Neuroscience 168, 130–137.
Goodyear, L.J., King, P.A., Hirshman, M.F., Thompson, C.M., Horton, E.D., Horton, E.S., 1990. Contractile activity increases plasma membrane glucose transporters in absence of insulin. Am. J. Phys. 258, E667–672.
Grivetti, L.E., Applegate, E.A., 1997. From Olympia to Atlanta: a cultural-historical perspective on diet and athletic training. J. Nutr. 127, 860S–868S.
Harris, R.C., Soderlund, K., Hultman, E., 1992. Elevation of creatine in resting and exercised muscle of normal subjects by creatine supplementation. Clin. Sci. 83, 367–374.
Hart, N., Sarga, L., Csende, Z., Koltai, E., Koch, L.G., Britton, S.L., Davies, K.J., Kouretas, D., Wessner, B., Radak, Z., 2013. Resveratrol enhances exercise training responses in rats selectively bred for high running performance. Food Chem. Toxicol. 61, 53–59.
Hart, N., Sarga, L., Csende, Z., Koch, L.G., Britton, S.L., Davies, K.J., Radak, Z., 2014. Resveratrol attenuates exercise-induced adaptive responses in rats selectively bred for low running performance. Dose-Response 12, 57–71.
Holick, M.F., 2005. The vitamin D epidemic and its health consequences. J. Nutr. 135, 2739S–2748S.
Kerksick, C.M., Arent, S., Schoenfeld, B.J., Stout, J.R., Campbell, B., Wilborn, C.D., Taylor, L., Kalman, D., Smith-Ryan, A.E., Kreider, R.B., Willoughby, D., Arciero, P.J., VanDusseldorp, T.A., Ormsbee, M.J., Wildman, R., Greenwood, M., Ziegenfuss, T.N., Aragon, A.A., Antonio, J., 2017. International society of sports nutrition position stand: nutrient timing. J. Int. Soc. Sports Nutr. 14, 33.

Kimber, N.E., Cameron-Smith, D., McGee, S.L., Hargreaves, M., 2013. Skeletal muscle fat metabolism after exercise in humans: influence of fat availability. J. Appl. Physiol. 114, 1577–1585.

Kreider, R.B., 2003. Effects of creatine supplementation on performance and training adaptations. Mol. Cell. Biochem. 244, 89–94.

Lappe, J., Cullen, D., Haynatzki, G., Recker, R., Ahlf, R., Thompson, K., 2008. Calcium and vitamin D supplementation decreases incidence of stress fractures in female navy recruits. J. Bone Miner. Res. 23, 741–749.

McNaughton, L.R., 1992. Sodium bicarbonate ingestion and its effects on anaerobic exercise of various durations. J. Sports Sci. 10, 425–435.

McNaughton, L.R., Siegler, J., Midgley, A., 2008. Ergogenic effects of sodium bicarbonate. Curr. Sports Med. Rep. 7, 230–236.

Mifflin, M.D., St Jeor, S.T., Hill, L.A., Scott, B.J., Daugherty, S.A., Koh, Y.O., 1990. A new predictive equation for resting energy expenditure in healthy individuals. Am. J. Clin. Nutr. 51, 241–247.

Molteni, R., Wu, A., Vaynman, S., Ying, Z., Barnard, R.J., Gomez-Pinilla, F., 2004. Exercise reverses the harmful effects of consumption of a high-fat diet on synaptic and behavioral plasticity associated to the action of brain-derived neurotrophic factor. Neuroscience 123, 429–440.

Nikolaidis, M.G., Kerksick, C.M., Lamprecht, M., McAnulty, S.R., 2012. Does vitamin C and E supplementation impair the favorable adaptations of regular exercise? Oxidative Med. Cell. Longev. 2012, 707941. https://doi.org/10.1155/2012/707941.

Romijn, J.A., Coyle, E.F., Sidossis, L.S., Gastaldelli, A., Horowitz, J.F., Endert, E., Wolfe, R.R., 1993. Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. Am. J. Phys. 265, E380–391.

Sale, C., Saunders, B., Hudson, S., Wise, J.A., Harris, R.C., Sunderland, C.D., 2011. Effect of beta-alanine plus sodium bicarbonate on high-intensity cycling capacity. Med. Sci. Sports Exerc. 43, 1972–1978.

Saunders, M.J., Kane, M.D., Todd, M.K., 2004. Effects of a carbohydrate-protein beverage on cycling endurance and muscle damage. Med. Sci. Sports Exerc. 36, 1233–1238.

Sawka, M.N., Noakes, T.D., 2007. Does dehydration impair exercise performance? Med. Sci. Sports Exerc. 39, 1209–1217.

Smith, J.W., Zachwieja, J.J., Peronnet, F., Passe, D.H., Massicotte, D., Lavoie, C., Pascoe, D.D., 2010. Fuel selection and cycling endurance performance with ingestion of [13C]glucose: evidence for a carbohydrate dose response. J. Appl. Physiol. 108, 1520–1529.

Stellingwerff, T., 2013. Contemporary nutrition approaches to optimize elite marathon performance. Int. J. Sports Physiol. Perform. 8, 573–578.

Tarnopolsky, M.A., 1999. Protein and physical performance. Curr. Opin. Clin. Nutr. Metab. Care 2, 533–537.

Tarnopolsky, M.A., 2010. Caffeine and creatine use in sport. Ann. Nutr. Metab. 57 (Suppl. 2), 1–8.

Volek, J.S., Kraemer, W.J., Bush, J.A., Incledon, T., Boetes, M., 1997. Testosterone and cortisol in relationship to dietary nutrients and resistance exercise. J. Appl. Physiol. 82, 49–54.

Waller, M.F., Haymes, E.M., 1996. The effects of heat and exercise on sweat iron loss. Med. Sci. Sports Exerc. 28, 197–203.

BIBLIOGRAPHY

Andersen, L.B., 1995. Physical activity and physical fitness as protection against premature disease or death. Scand. J. Med. Sci. Sports 5, 318–328.

Antonelli, J.A., Jones, L.W., Banez, L.L., Thomas, J.A., Anderson, K., Taylor, L.A., Gerber, L., Anderson, T., Hoyo, C., Grant, D., Freedland, S.J., 2009. Exercise and prostate cancer risk in a cohort of veterans undergoing prostate needle biopsy. J. Urol. 182, 2226–2231.

Atlantis, E., Chow, C.M., Kirby, A., Fiatarone Singh, M.A., 2006. Worksite intervention effects on physical health: a randomized controlled trial. Health Promot. Int. 21, 191–200.

Bernstein, L., 2009. Exercise and breast cancer prevention. Curr. Oncol. Rep. 11, 490–496.

Blair, S.N., Kohl 3rd, H.W., Barlow, C.E., Paffenbarger Jr., R.S., Gibbons, L.W., Macera, C.A., 1995. Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. JAMA 273, 1093–1098.

Boyle, T., Keegel, T., Bull, F., Heyworth, J., Fritschi, L., 2012. Physical activity and risks of proximal and distal colon cancers: a systematic review and meta-analysis. J. Natl. Cancer Inst. 104, 1548–1561.

Bramble, D.M., Lieberman, D.E., 2004. Endurance running and the evolution of Homo. Nature 432, 345–352.

Brien, S.E., Katzmarzyk, P.T., Craig, C.L., Gauvin, L., 2007. Physical activity, cardiorespiratory fitness and body mass index as predictors of substantial weight gain and obesity: the Canadian physical activity longitudinal study. Can. J. Public Health 98, 121–124.

Bullitt, E., Rahman, F.N., Smith, J.K., Kim, E., Zeng, D., Katz, L.M., Marks, B.L., 2009. The effect of exercise on the cerebral vasculature of healthy aged subjects as visualized by MR angiography. AJNR Am. J. Neuroradiol. 30, 1857–1863.

Butterfield, D.A., Howard, B.J., Yatin, S., Allen, K.L., Carney, J.M., 1997. Free radical oxidation of brain proteins in accelerated senescence and its modulation by *N*-tert-butyl-alpha-phenylnitrone. Proc. Natl. Acad. Sci. U. S. A. 94, 674–678.

Canani, R.B., Costanzo, M.D., Leone, L., Pedata, M., Meli, R., Calignano, A., 2011. Potential beneficial effects of butyrate in intestinal and extraintestinal diseases. World J. Gastroenterol. 17, 1519–1528.

Chakravarthy, M.V., Booth, F.W., 2004. Eating, exercise, and "thrifty" genotypes: connecting the dots toward an evolutionary understanding of modern chronic diseases. J. Appl. Physiol. 96, 3–10.

Charkoudian, N., Joyner, M.J., 2004. Physiologic considerations for exercise performance in women. Clin. Chest Med. 25, 247–255.

Colcombe, S.J., Erickson, K.I., Scalf, P.E., Kim, J.S., Prakash, R., McAuley, E., Elavsky, S., Marquez, D.X., Hu, L., Kramer, A.F., 2006. Aerobic exercise training increases brain volume in aging humans. J. Gerontol. A Biol. Sci. Med. Sci. 61, 1166–1170.

Conney, A.H., Lou, Y.R., Nghiem, P., Bernard, J.J., Wagner, G.C., Lu, Y.P., 2013. Inhibition of UVB-induced nonmelanoma skin cancer: a path from tea to caffeine to exercise to decreased tissue fat. Top. Curr. Chem. 329, 61–72.

Doyle, L.M., Roberts, B.L., 2006. Exercise enhances axonal growth and functional recovery in the regenerating spinal cord. Neuroscience 141, 321–327.

Dunstan, D.W., Salmon, J., Healy, G.N., Shaw, J.E., Jolley, D., Zimmet, P.Z., Owen, N., 2007. Association of television viewing with fasting and 2-h postchallenge plasma glucose levels in adults without diagnosed diabetes. Diabetes Care 30, 516–522.

Dvorak, R.V., Tchernof, A., Starling, R.D., Ades, P.A., DiPietro, L., Poehlman, E.T., 2000. Respiratory fitness, free living physical activity, and cardiovascular disease risk in older individuals: a doubly labeled water study. J. Clin. Endocrinol. Metab. 85, 957–963.

Erickson, K.I., Voss, M.W., Prakash, R.S., Basak, C., Szabo, A., Chaddock, L., Kim, J.S., Heo, S., Alves, H., White, S.M., Wojcicki, T.R., Mailey, E., Vieira, V.J., Martin, S.A., Pence, B.D., Woods, J.A., McAuley, E., Kramer, A.F., 2011. Exercise training increases size of hippocampus and improves memory. Proc. Natl. Acad. Sci. U. S. A. 108, 3017–3022.

Esser, K.A., Harpole, C.E., Prins, G.S., Diamond, A.M., 2009. Physical activity reduces prostate carcinogenesis in a transgenic model. Prostate 69, 1372–1377.

Fotuhi, M., Do, D., Jack, C., 2012. Modifiable factors that alter the size of the hippocampus with ageing. Nat. Rev. Neurol. 8, 189–202.

Gill, S.R., Pop, M., Deboy, R.T., Eckburg, P.B., Turnbaugh, P.J., Samuel, B.S., Gordon, J.I., Relman, D.A., Fraser-Liggett, C.M., Nelson, K.E., 2006. Metagenomic analysis of the human distal gut microbiome. Science 312, 1355–1359.

Grenham, S., Clarke, G., Cryan, J.F., Dinan, T.G., 2011. Brain-gut-microbe communication in health and disease. Front. Physiol. 2, 94.

Hart, N., Sarga, L., Csende, Z., Koltai, E., Koch, L.G., Britton, S.L., Davies, K.J., Kouretas, D., Wessner, B., Radak, Z., 2013. Resveratrol enhances exercise training responses in rats selectively bred for high running performance. Food Chem. Toxicol. 61, 53–59.

Healy, G.N., Wijndaele, K., Dunstan, D.W., Shaw, J.E., Salmon, J., Zimmet, P.Z., Owen, N., 2008. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian diabetes, obesity and lifestyle study (AusDiab). Diabetes Care 31, 369–371.

Holzschneider, K., Wolbers, T., Roder, B., Hotting, K., 2012. Cardiovascular fitness modulates brain activation associated with spatial learning. Neuroimage 59, 3003–3014.

Hu, F.B., Li, T.Y., Colditz, G.A., Willett, W.C., Manson, J.E., 2003. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. JAMA 289, 1785–1791.

Hussain, S.O., Barbato, J.C., Koch, L.G., Metting, P.J., Britton, S.L., 2001. Cardiac function in rats selectively bred for low- and high-capacity running. Am. J. Physiol. Regul. Integr. Comp. Physiol. 281, R1787–1791.

Katzmarzyk, P.T., Church, T.S., Craig, C.L., Bouchard, C., 2009. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med. Sci. Sports Exerc. 41, 998–1005.

Koch, L.G., Kemi, O.J., Qi, N., Leng, S.X., Bijma, P., Gilligan, L.J., Wilkinson, J.E., Wisloff, H., Hoydal, M.A., Rolim, N., Abadir, P.M., van Grevenhof, E.M., Smith, G.L., Burant, C.F., Ellingsen, O., Britton, S.L., Wisloff, U., 2011. Intrinsic aerobic capacity sets a divide for aging and longevity. Circ. Res. 109, 1162–1172.

Koch, L.G., Britton, S.L., Wisloff, U., 2012. A rat model system to study complex disease risks, fitness, aging, and longevity. Trends Cardiovasc. Med. 22, 29–34.

Koltai, E., Zhao, Z., Lacza, Z., Cselenyak, A., Vacz, G., Nyakas, C., Boldogh, I., Ichinoseki-Sekine, N., Radak, Z., 2011. Combined exercise and insulin-like growth factor-1 supplementation induces neurogenesis in old rats, but do not attenuate age-associated DNA damage. Rejuvenation Res. 14, 585–596.

Laukkanen, J.A., Laaksonen, D., Lakka, T.A., Savonen, K., Rauramaa, R., Makikallio, T., Kurl, S., 2009. Determinants of cardiorespiratory fitness in men aged 42 to 60 years with and without cardiovascular disease. Am. J. Cardiol. 103, 1598–1604.

Liu, Y., Hu, F., Li, D., Wang, F., Zhu, L., Chen, W., Ge, J., An, R., Zhao, Y., 2011. Does physical activity reduce the risk of prostate cancer? A systematic review and meta-analysis. Eur. Urol. 60, 1029–1044.

Lou, S.J., Liu, J.Y., Chang, H., Chen, P.J., 2008. Hippocampal neurogenesis and gene expression depend on exercise intensity in juvenile rats. Brain Res. 1210, 48–55.

Madduri, S., Papaloizos, M., Gander, B., 2009. Synergistic effect of GDNF and NGF on axonal branching and elongation in vitro. Neurosci. Res. 65, 88–97.

Maesako, M., Uemura, K., Kubota, M., Kuzuya, A., Sasaki, K., Hayashida, N., Asada-Utsugi, M., Watanabe, K., Uemura, M., Kihara, T., Takahashi, R., Shimohama, S., Kinoshita, A., 2012. Exercise is more effective than diet control in preventing high fat diet-induced

beta-amyloid deposition and memory deficit in amyloid precursor protein transgenic mice. J. Biol. Chem. 287, 23024–23033.
Matsumoto, M., Inoue, R., Tsukahara, T., Ushida, K., Chiji, H., Matsubara, N., Hara, H., 2008. Voluntary running exercise alters microbiota composition and increases n-butyrate concentration in the rat cecum. Biosci. Biotechnol. Biochem. 72, 572–576.
Radak, Z. (Ed.), 2004. Exercise and Diseases: Prevention through Training. Meyer and Meyer Sport, Aachen.
Radak, Z., Kaneko, T., Tahara, S., Nakamoto, H., Pucsok, J., Sasvari, M., Nyakas, C., Goto, S., 2001a. Regular exercise improves cognitive function and decreases oxidative damage in rat brain. Neurochem. Int. 38, 17–23.
Radak, Z., Taylor, A.W., Sasvari, M., Ohno, H., Horkay, B., Furesz, J., Gaal, D., Kanel, T., 2001b. Telomerase activity is not altered by regular strenuous exercise in skeletal muscle or by sarcoma in liver of rats. Redox Rep. 6, 99–103.
Radak, Z., Gaal, D., Taylor, A.W., Kaneko, T., Tahara, S., Nakamoto, H., Goto, S., 2002. Attenuation of the development of murine solid leukemia tumor by physical exercise. Antioxid. Redox Signal. 4, 213–219.
Radak, Z., Chung, H.Y., Naito, H., Takahashi, R., Jung, K.J., Kim, H.J., Goto, S., 2004. Age-associated increase in oxidative stress and nuclear factor kappaB activation are attenuated in rat liver by regular exercise. FASEB J. 18, 749–750.
Radak, Z., Kumagai, S., Taylor, A.W., Naito, H., Goto, S., 2007. Effects of exercise on brain function: role of free radicals. Appl. Physiol. Nutr. Metab. 32, 942–946.
Radak, Z., Hart, N., Sarga, L., Koltai, E., Atalay, M., Ohno, H., Boldogh, I., 2010. Exercise plays a preventive role against Alzheimer's disease. J. Alzheimers Dis. 20, 777–783.
Radak, Z., Zhao, Z., Goto, S., Koltai, E., 2011. Age-associated neurodegeneration and oxidative damage to lipids, proteins and DNA. Mol. Aspects Med. 32, 305–315.
Rebillard, A., Lefeuvre-Orfila, L., Gueritat, J., Cillard, J., 2013. Prostate cancer and physical activity: adaptive response to oxidative stress. Free Radic. Biol. Med. 60, 115–124.
Rothman, S.M., Griffioen, K.J., Wan, R., Mattson, M.P., 2012. Brain-derived neurotrophic factor as a regulator of systemic and brain energy metabolism and cardiovascular health. Ann. N.Y. Acad. Sci. 1264, 49–63.
Sarga, L., Hart, N., Koch, L.G., Britton, S.L., Hajas, G., Boldogh, I., Ba, X., Radak, Z., 2013. Aerobic endurance capacity affects spatial memory and SIRT1 is a potent modulator of 8-oxoguanine repair. Neuroscience 252, 326–336.
Sawada, S.S., Muto, T., Tanaka, H., Lee, I.M., Paffenbarger Jr., R.S., Shindo, M., Blair, S.N., 2003. Cardiorespiratory fitness and cancer mortality in Japanese men: a prospective study. Med. Sci. Sports Exerc. 35, 1546–1550.
Sea, J., Poon, K.S., McVary, K.T., 2009. Review of exercise and the risk of benign prostatic hyperplasia. Physician Sports Med. 37, 75–83.
Strasser, B., 2013. Physical activity in obesity and metabolic syndrome. Ann. N.Y. Acad. Sci. 1281, 141–159.
Tang, K., Xia, F.C., Wagner, P.D., Breen, E.C., 2010. Exercise-induced VEGF transcriptional activation in brain, lung and skeletal muscle. Respir. Physiol. Neurobiol. 170, 16–22.
Toldy, A., Atalay, M., Stadler, K., Sasvari, M., Jakus, J., Jung, K.J., Chung, H.Y., Nyakas, C., Radak, Z., 2009. The beneficial effects of nettle supplementation and exercise on brain lesion and memory in rat. J. Nutr. Biochem. 20, 974–981.
Totsikas, C., Rohm, J., Kantartzis, K., Thamer, C., Rittig, K., Machann, J., Schick, F., Hansel, J., Niess, A., Fritsche, A., Haring, H.U., Stefan, N., 2011. Cardiorespiratory fitness determines the reduction in blood pressure and insulin resistance during lifestyle intervention. J. Hypertens. 29, 1220–1227.
Tschentscher, M., Niederseer, D., Niebauer, J., 2013. Health benefits of Nordic walking: a systematic review. Am. J. Prev. Med. 44, 76–84.
Umar, A., Dunn, B.K., Greenwald, P., 2012. Future directions in cancer prevention. Nat. Rev. Cancer 12, 835–848.

Williams, P.T., 2001. Physical fitness and activity as separate heart disease risk factors: a meta-analysis. Med. Sci. Sports Exerc. 33, 754–761.
Wisloff, U., Najjar, S.M., Ellingsen, O., Haram, P.M., Swoap, S., Al-Share, Q., Fernstrom, M., Rezaei, K., Lee, S.J., Koch, L.G., Britton, S.L., 2005. Cardiovascular risk factors emerge after artificial selection for low aerobic capacity. Science 307, 418–420.
Zimmer, C., 2004. Human evolution. Faster than a hyena? Running may make humans special. Science 306, 1283.

cardiovascular diseases, Alzheimer's and Parkinson's diseases, osteoporosis, and age-related muscle atrophy. Frequent physical training is very important for the elderly. Average physical activity of young individuals is higher than that of the elderly, thus negative effects of physical inactivity are more significant in the latter, and therefore they are recommended to make time for frequent physical exercise. It provides an opportunity to maintain balance and prevent lifestyle diseases, and improve life quality and increase lifespan.

TEST QUESTIONS

1. What are the most important aging theories?
2. What is the maximal lifespan of humans and what factors determine average life expectancy?
3. What is a telomere and what is its role in aging?
4. What are free radicals and what is their role in aging?
5. What are the characteristics of age-related changes of the heart and how are they influenced by physical training?
6. How does physical training influence the aging of the nervous system?
7. How does physical training influence bone thinning?

BIBLIOGRAPHY

Bain, J., Duthie, M., Keene, J., 1979. Relationship of seminal plasma testosterone and dihydrotestosterone to sperm count and motility in man. Arch. Androl. 2, 35–39.

Carney, J.M., Starke-Reed, P.E., Oliver, C.N., Landum, R.W., Cheng, M.S., Wu, J.F., Floyd, R.A., 1991. Reversal of age-related increase in brain protein oxidation, decrease in enzyme activity, and loss in temporal and spatial memory by chronic administration of the spin-trapping compound *N*-tert-butyl-alpha-phenylnitrone. Proc. Natl. Acad. Sci. U. S. A. 88, 3633–3636.

Colcombe, S.J., Erickson, K.I., Raz, N., Webb, A.G., Cohen, N.J., McAuley, E., Kramer, A.F., 2003. Aerobic fitness reduces brain tissue loss in aging humans. J. Gerontol. A Biol. Sci. Med. Sci. 58, 176–180.

Colcombe, S.J., Kramer, A.F., Erickson, K.I., Scalf, P., McAuley, E., Cohen, N.J., Webb, A., Jerome, G.J., Marquez, D.X., Elavsky, S., 2004a. Cardiovascular fitness, cortical plasticity, and aging. Proc. Natl. Acad. Sci. U. S. A. 101, 3316–3321.

Colcombe, S.J., Kramer, A.F., McAuley, E., Erickson, K.I., Scalf, P., 2004b. Neurocognitive aging and cardiovascular fitness: recent findings and future directions. J. Mol. Neurosci. 24, 9–14.

Colcombe, S.J., Erickson, K.I., Scalf, P.E., Kim, J.S., Prakash, R., McAuley, E., Elavsky, S., Marquez, D.X., Hu, L., Kramer, A.F., 2006. Aerobic exercise training increases brain volume in aging humans. J. Gerontol. A Biol. Sci. Med. Sci. 61, 1166–1170.

Erickson, K.I., Voss, M.W., Prakash, R.S., Basak, C., Szabo, A., Chaddock, L., Kim, J.S., Heo, S., Alves, H., White, S.M., Wojcicki, T.R., Mailey, E., Vieira, V.J., Martin, S.A., Pence, B.D., Woods, J.A., McAuley, E., Kramer, A.F., 2011. Exercise training increases size of hippocampus and improves memory. Proc. Natl. Acad. Sci. U. S. A. 108, 3017–3022.

Harman, D., 1956. Aging: a theory based on free radical and radiation chemistry. J. Gerontol. 11, 298–300.

Lacza, G., Radak, Z., 2013. Is physical activity an elixir? Orv. Hetil. 154, 764–768.

Lazarov, O., Robinson, J., Tang, Y.P., Hairston, I.S., Korade-Mirnics, Z., Lee, V.M., Hersh, L.B., Sapolsky, R.M., Mirnics, K., Sisodia, S.S., 2005. Environmental enrichment reduces Abeta levels and amyloid deposition in transgenic mice. Cell 120, 701–713.

Linskens, M.H., Harley, C.B., West, M.D., Campisi, J., Hayflick, L., 1995. Replicative senescence and cell death. Science 267, 17.

Radak, Z. (Ed.), 2004. Exercise and Diseases: Prevention Through Training. Meyer and Meyer Sport, Aachen.

Radak, Z., Kaneko, T., Tahara, S., Nakamoto, H., Ohno, H., Sasvari, M., Nyakas, C., Goto, S., 1999. The effect of exercise training on oxidative damage of lipids, proteins, and DNA in rat skeletal muscle: evidence for beneficial outcomes. Free Radic. Biol. Med. 27, 69–74.

Radak, Z., Kaneko, T., Tahara, S., Nakamoto, H., Pucsok, J., Sasvari, M., Nyakas, C., Goto, S., 2001. Regular exercise improves cognitive function and decreases oxidative damage in rat brain. Neurochem. Int. 38, 17–23.

Radak, Z., Naito, H., Kaneko, T., Tahara, S., Nakamoto, H., Takahashi, R., Cardozo-Pelaez, F., Goto, S., 2002. Exercise training decreases DNA damage and increases DNA repair and resistance against oxidative stress of proteins in aged rat skeletal muscle. Pflugers Arch. - Eur. J. Physiol. 445, 273–278.

Radak, Z., Chung, H.Y., Naito, H., Takahashi, R., Jung, K.J., Kim, H.J., Goto, S., 2004. Age-associated increase in oxidative stress and nuclear factor kappaB activation are attenuated in rat liver by regular exercise. FASEB J. 18, 749–750.

Radak, Z., Toldy, A., Szabo, Z., Siamilis, S., Nyakas, C., Silye, G., Jakus, J., Goto, S., 2006. The effects of training and detraining on memory, neurotrophins and oxidative stress markers in rat brain. Neurochem. Int. 49, 387–392.

Radak, Z., Chung, H.Y., Goto, S., 2008a. Systemic adaptation to oxidative challenge induced by regular exercise. Free Radic. Biol. Med. 44, 153–159.

Radak, Z., Chung, H.Y., Koltai, E., Taylor, A.W., Goto, S., 2008b. Exercise, oxidative stress and hormesis. Ageing Res. Rev. 7, 34–42.

Radak, Z., Hart, N., Sarga, L., Koltai, E., Atalay, M., Ohno, H., Boldogh, I., 2010. Exercise plays a preventive role against Alzheimer's disease. J. Alzheimers Dis. 20, 777–783.

Radak, Z., Koltai, E., Taylor, A.W., Higuchi, M., Kumagai, S., Ohno, H., Goto, S., Boldogh, I., 2013. Redox-regulating sirtuins in aging, caloric restriction, and exercise. Free Radic. Biol. Med. 58, 87–97.

Radak, Z., Ihasz, F., Koltai, E., Goto, S., Taylor, A.W., Boldogh, I., 2014. The redox-associated adaptive response of brain to physical exercise. Free Radic. Res. 48, 84–92.

Sanchis-Gomar, F., Olaso-Gonzalez, G., Corella, D., Gomez-Cabrera, M.C., Vina, J., 2011. Increased average longevity among the "Tour de France" cyclists. Int. J. Sports Med. 32, 644–647.

Szilard, L., 1959. On the nature of the aging process. Proc. Natl. Acad. Sci. U. S. A. 45, 30–45.

van Praag, H., Christie, B.R., Sejnowski, T.J., Gage, F.H., 1999a. Running enhances neurogenesis, learning, and long-term potentiation in mice. Proc. Natl. Acad. Sci. U. S. A. 96, 13427–13431.

van Praag, H., Kempermann, G., Gage, F.H., 1999b. Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus. Nat. Neurosci. 2, 266–270.

Ziaaldini, M.M., Koltai, E., Csende, Z., Goto, S., Boldogh, I., Taylor, A.W., Radak, Z., 2015. Exercise training increases anabolic and attenuates catabolic and apoptotic processes in aged skeletal muscle of male rats. Exp. Gerontol. 67, 9–14.

those measured in experimental mice, and verify the results measured by Marton's group (Marton et al., 2015).

Similar examinations were done on power performance and miRNA systems were tested on groups that responded well or poorly to power training. Decreased levels of miRNA-378, miRNA-29a, and miRNA-26a were measured in the muscle of the group with the weaker response to training, and the level of miRNA-378 correlated strongly with the increasing size of the muscle cross-sectional area (Davidsen et al., 2011). There are significant individual differences in the level of miRNAs; however, they should be further examined to discover their role in sport performance, as that would be helpful in individual sport selection.

11.4 SUMMARY

Genetics play a very important role in sport performance. However, outstanding performance and individual competence depend on a complex system of abilities of which genes are only a portion.

The complexity of sport performance is reflected by the strong differences in individuals with differential congenital and acquired traits and personality. Epigenetic effects are extremely important, since lifestyle affect not only the life of the individual but its inheritable epigenetic changes reappear in descendants. The positive effects of physical training in prevention and healing manifest through epigenetic modification. The role of genetic factors in professional sports is important; however, a correlation between gene polymorphisms and sport performance has not yet been established.

TEST QUESTIONS

1. What is a gene?
2. What traits can be determined by genetic factors?
3. What is the role of sport genomics?
4. What genes are associated with endurance?
5. What genes are associated with power?
6. What are the advantages and limits of sport genetics?

BIBLIOGRAPHY

Akhmetov, I.I., Astranenkova, I.V., Rogozkin, V.A., 2007. Association of PPARD gene polymorphism with human physical performance. Mol. Biol. 41, 852–857.

Alvarez, R., Terrados, N., Ortolano, R., Iglesias-Cubero, G., Reguero, J.R., Batalla, A., Cortina, A., Fernandez-Garcia, B., Rodriguez, C., Braga, S., Alvarez, V., Coto, E., 2000. Genetic variation in the renin-angiotensin system and athletic performance. Eur. J. Appl. Physiol. 82, 117–120.

Ash, G.I., Scott, R.A., Deason, M., Dawson, T.A., Wolde, B., Bekele, Z., Teka, S., Pitsiladis, Y.P., 2011. No association between ACE gene variation and endurance athlete status in Ethiopians. Med. Sci. Sports Exerc. 43, 590–597.

Berman, Y., North, K.N., 2010. A gene for speed: the emerging role of alpha-actinin-3 in muscle metabolism. Physiology 25, 250–259.

Bray, M.S., Hagberg, J.M., Perusse, L., Rankinen, T., Roth, S.M., Wolfarth, B., Bouchard, C., 2009. The human gene map for performance and health-related fitness phenotypes: the 2006–2007 update. Med. Sci. Sports Exerc. 41, 35–73.

Davidsen, P.K., Gallagher, I.J., Hartman, J.W., Tarnopolsky, M.A., Dela, F., Helge, J.W., Timmons, J.A., Phillips, S.M., 2011. High responders to resistance exercise training demonstrate differential regulation of skeletal muscle microRNA expression. J. Appl. Physiol. 110, 309–317.

Day, S.H., Gohlke, P., Dhamrait, S.S., Williams, A.G., 2007. No correlation between circulating ACE activity and VO2max or mechanical efficiency in women. Eur. J. Appl. Physiol. 99, 11–18.

Dionne, F.T., Turcotte, L., Thibault, M.C., Boulay, M.R., Skinner, J.S., Bouchard, C., 1993. Mitochondrial DNA sequence polymorphism, VO2max, and response to endurance training. Med. Sci. Sports Exerc. 25, 766–774.

Dolinoy, D.C., Weinhouse, C., Jones, T.R., Rozek, L.S., Jirtle, R.L., 2010. Variable histone modifications at the A(vy) metastable epiallele. Epigenetics 5, 637–644.

Doring, F., Onur, S., Fischer, A., Boulay, M.R., Perusse, L., Rankinen, T., Rauramaa, R., Wolfarth, B., Bouchard, C., 2010. A common haplotype and the Pro582Ser polymorphism of the hypoxia-inducible factor-1alpha (HIF1A) gene in elite endurance athletes. J. Appl. Physiol. 108, 1497–1500.

Eynon, N., Ruiz, J.R., Meckel, Y., Moran, M., Lucia, A., 2011. Mitochondrial biogenesis related endurance genotype score and sports performance in athletes. Mitochondrion 11, 64–69.

Fraga, M.F., Ballestar, E., Paz, M.F., Ropero, S., Setien, F., Ballestar, M.L., Heine-Suner, D., Cigudosa, J.C., Urioste, M., Benitez, J., Boix-Chornet, M., Sanchez-Aguilera, A., Ling, C., Carlsson, E., Poulsen, P., Vaag, A., Stephan, Z., Spector, T.D., Wu, Y.Z., Plass, C., Esteller, M., 2005. Epigenetic differences arise during the lifetime of monozygotic twins. Proc. Natl. Acad. Sci. U. S. A. 102, 10604–10609.

Gallagher, I.J., Scheele, C., Keller, P., Nielsen, A.R., Remenyi, J., Fischer, C.P., Roder, K., Babraj, J., Wahlestedt, C., Hutvagner, G., Pedersen, B.K., Timmons, J.A., 2010. Integration of microRNA changes in vivo identifies novel molecular features of muscle insulin resistance in type 2 diabetes. Genome Med. 2, 9.

Gomez-Pinilla, F., Zhuang, Y., Feng, J., Ying, Z., Fan, G., 2011. Exercise impacts brain-derived neurotrophic factor plasticity by engaging mechanisms of epigenetic regulation. Eur. J. Neurosci. 33, 383–390.

Grenda, A., Leonska-Duniec, A., Cieszczyk, P., Zmijewski, P., 2014. Bdkrb2 gene −9/+9 polymorphism and swimming performance. Biol. Sport 31, 109–113.

Hittel, D.S., Berggren, J.R., Shearer, J., Boyle, K., Houmard, J.A., 2009. Increased secretion and expression of myostatin in skeletal muscle from extremely obese women. Diabetes 58, 30–38.

Keller, P., Vollaard, N.B., Gustafsson, T., Gallagher, I.J., Sundberg, C.J., Rankinen, T., Britton, S.L., Bouchard, C., Koch, L.G., Timmons, J.A., 2011. A transcriptional map of the impact of endurance exercise training on skeletal muscle phenotype. J. Appl. Physiol. 110, 46–59.

Kohn, T.A., Essen-Gustavsson, B., Myburgh, K.H., 2007. Do skeletal muscle phenotypic characteristics of Xhosa and Caucasian endurance runners differ when matched for training and racing distances? J. Appl. Physiol. 103, 932–940.

Lucia, A., Gomez-Gallego, F., Barroso, I., Rabadan, M., Bandres, F., San Juan, A.F., Chicharro, J.L., Ekelund, U., Brage, S., Earnest, C.P., Wareham, N.J., Franks, P.W., 2005. PPARGC1A genotype (Gly482Ser) predicts exceptional endurance capacity in European men. J. Appl. Physiol. 99, 344–348.

Lucia, A., Moran, M., Zihong, H., Ruiz, J.R., 2010. Elite athletes: are the genes the champions? Int. J. Sports Physiol. Perform. 5, 98–102.
Marino, F.E., Lambert, M.I., Noakes, T.D., 2004. Superior performance of African runners in warm humid but not in cool environmental conditions. J. Appl. Physiol. 96, 124–130.
Marton, O., Koltai, E., Takeda, M., Koch, L.G., Britton, S.L., Davies, K.J., Boldogh, I., Radak, Z., 2015. Mitochondrial biogenesis-associated factors underlie the magnitude of response to aerobic endurance training in rats. Pflugers Arch. - Eur. J. Physiol. 467, 779–788.
Matsuda, R., Spector, D.H., Strohman, R.C., 1983. Regenerating adult chicken skeletal muscle and satellite cell cultures express embryonic patterns of myosin and tropomyosin isoforms. Dev. Biol. 100, 478–488.
McGee, S.L., Fairlie, E., Garnham, A.P., Hargreaves, M., 2009. Exercise-induced histone modifications in human skeletal muscle. J. Physiol. 587, 5951–5958.
Mustafina, L.J., Naumov, V.A., Cieszczyk, P., Popov, D.V., Lyubaeva, E.V., Kostryukova, E.S., Fedotovskaya, O.N., Druzhevskaya, A.M., Astratenkova, I.V., Glotov, A.S., Alexeev, D.G., Mustafina, M.M., Egorova, E.S., Maciejewska-Karlowska, A., Larin, A.K., Generozov, E.V., Nurullin, R.E., Jastrzebski, Z., Kulemin, N.A., Ospanova, E.A., Pavlenko, A.V., Sawczuk, M., Akimov, E.B., Danilushkina, A.A., Zmijewski, P., Vinogradova, O.L., Govorun, V.M., Ahmetov, I.I., 2014. AGTR2 gene polymorphism is associated with muscle fibre composition, athletic status and aerobic performance. Exp. Physiol. 99, 1042–1052.
Niemi, A.K., Majamaa, K., 2005. Mitochondrial DNA and ACTN3 genotypes in Finnish elite endurance and sprint athletes. Eur. J. Hum. Genet. 13, 965–969.
Onywera, V.O., Scott, R.A., Boit, M.K., Pitsiladis, Y.P., 2006. Demographic characteristics of elite Kenyan endurance runners. J. Sports Sci. 24, 415–422.
Pandorf, C.E., Haddad, F., Wright, C., Bodell, P.W., Baldwin, K.M., 2009. Differential epigenetic modifications of histones at the myosin heavy chain genes in fast and slow skeletal muscle fibers and in response to muscle unloading. Am. J. Physiol. Cell Physiol. 297, C6–16.
Rankinen, T., Roth, S.M., Bray, M.S., Loos, R., Perusse, L., Wolfarth, B., Hagberg, J.M., Bouchard, C., 2010. Advances in exercise, fitness, and performance genomics. Med. Sci. Sports Exerc. 42, 835–846.
Rubio, J.C., Martin, M.A., Rabadan, M., Gomez-Gallego, F., San Juan, A.F., Alonso, J.M., Chicharro, J.L., Perez, M., Arenas, J., Lucia, A., 2005. Frequency of the C34T mutation of the AMPD1 gene in world-class endurance athletes: does this mutation impair performance? J. Appl. Physiol. 98, 2108–2112.
Schroder, W., Klostermann, A., Distl, O., 2011. Candidate genes for physical performance in the horse. Vet. J. 190, 39–48.
Scott, R.A., Moran, C., Wilson, R.H., Onywera, V., Boit, M.K., Goodwin, W.H., Gohlke, P., Payne, J., Montgomery, H., Pitsiladis, Y.P., 2005. No association between angiotensin converting enzyme (ACE) gene variation and endurance athlete status in Kenyans. Comp. Biochem. Physiol. A Mol. Integr. Physiol. 141, 169–175.
Sonna, L.A., Sharp, M.A., Knapik, J.J., Cullivan, M., Angel, K.C., Patton, J.F., Lilly, C.M., 2001. Angiotensin-converting enzyme genotype and physical performance during US Army basic training. J. Appl. Physiol. 91, 1355–1363.
Tringali, C., Brivio, I., Stucchi, B., Silvestri, I., Scurati, R., Michielon, G., Alberti, G., Venerando, B., 2014. Prevalence of a characteristic gene profile in high-level rhythmic gymnasts. J. Sports Sci. 32, 1409–1415.
Vaughan, D., Huber-Abel, F.A., Graber, F., Hoppeler, H., Fluck, M., 2013. The angiotensin converting enzyme insertion/deletion polymorphism alters the response of muscle energy supply lines to exercise. Eur. J. Appl. Physiol. 113, 1719–1729.
Wisloff, U., Najjar, S.M., Ellingsen, O., Haram, P.M., Swoap, S., Al-Share, Q., Fernstrom, M., Rezaei, K., Lee, S.J., Koch, L.G., Britton, S.L., 2005. Cardiovascular risk factors emerge after artificial selection for low aerobic capacity. Science 307, 418–420.

preparational period, the ability which mostly limits the performance, must be most extensively improved and in this period the duration of the training load is emphasized. On the other hand, during the competitive period the intensity increases, leading to enhanced performance.

TEST QUESTIONS

1. What are the components of 1-year periodization?
2. What factors determine goal settings in periodization?
3. What kind of loading patterns do you know?
4. What are the physiological effects of a micro-cycle that aims to improve aerobic endurance?
5. What are the physiological effects of a micro-cycle that aims to improve explosive strength?
6. What are the physiological effects of a micro-cycle that aims to improve speed?
7. How would you prepare long-term development exercise program for children?

BIBLIOGRAPHY

Abe, T., Kitaoka, Y., Kikuchi, D.M., Takeda, K., Numata, O., Takemasa, T., 2015. High-intensity interval training-induced metabolic adaptation coupled with an increase in Hif-1alpha and glycolytic protein expression. J. Appl. Physiol. 119, 1297–1302.

Adams, S.C., DeLorey, D.S., Davenport, M.H., Stickland, M.K., Fairey, A.S., North, S., Szczotka, A., Courneya, K.S., 2017. Effects of high-intensity aerobic interval training on cardiovascular disease risk in testicular cancer survivors: a phase 2 randomized controlled trial. Cancer 123, 4057–4065.

Afzalpour, M.E., Chadorneshin, H.T., Foadoddini, M., Eivari, H.A., 2015. Comparing interval and continuous exercise training regimens on neurotrophic factors in rat brain. Physiol. Behav. 147, 78–83.

Andersen, P., Henriksson, J., 1977. Capillary supply of the quadriceps femoris muscle of man: adaptive response to exercise. J. Physiol. 270, 677–690.

Baar, K., 2014. Using molecular biology to maximize concurrent training. Sports Med. 44 (Suppl. 2), S117–125.

Baggish, A.L., Park, J., Min, P.K., Isaacs, S., Parker, B.A., Thompson, P.D., Troyanos, C., D'Hemecourt, P., Dyer, S., Thiel, M., Hale, A., Chan, S.Y., 2014. Rapid upregulation and clearance of distinct circulating microRNAs after prolonged aerobic exercise. J. Appl. Physiol. 116, 522–531.

Bangsbo, J., Mohr, M., Krustrup, P., 2006. Physical and metabolic demands of training and match-play in the elite football player. J. Sports Sci. 24, 665–674.

Bartolomei, S., Hoffman, J.R., Merni, F., Stout, J.R., 2014. A comparison of traditional and block periodized strength training programs in trained athletes. J. Strength Cond. Res. 28, 990–997.

Behm, D.G., Young, J.D., Whitten, J.H.D., Reid, J.C., Quigley, P.J., Low, J., Li, Y., Lima, C.D., Hodgson, D.D., Chaouachi, A., Prieske, O., Granacher, U., 2017. Effectiveness of traditional strength vs. power training on muscle strength, power and speed with youth: a systematic review and meta-analysis. Front. Physiol. 8, 423.

Bishop, D.J., Granata, C., Eynon, N., 2014. Can we optimise the exercise training prescription to maximise improvements in mitochondria function and content? Biochim. Biophys. Acta 1840, 1266–1275.

Borer, K.T., 1995. The effects of exercise on growth. Sports Med. 20, 375–397.

Bradley, H., Shaw, C.S., Worthington, P.L., Shepherd, S.O., Cocks, M., Wagenmakers, A.J., 2014. Quantitative immunofluorescence microscopy of subcellular GLUT4 distribution in human skeletal muscle: effects of endurance and sprint interval training. Phys. Rep. 2.

Brooks, G.A., 1986. Lactate production under fully aerobic conditions: the lactate shuttle during rest and exercise. Fed. Proc. 45, 2924–2929.

Budnar Jr., R.G., Duplanty, A.A., Hill, D.W., McFarlin, B.K., Vingren, J.L., 2014. The acute hormonal response to the kettlebell swing exercise. J. Strength Cond. Res. 28, 2793–2800.

Casadio, J.R., Storey, A.G., Merien, F., Kilding, A.E., Cotter, J.D., Laursen, P.B., 2017. Acute effects of heated resistance exercise in female and male power athletes. Eur. J. Appl. Physiol. 117, 1965–1976.

Chan, M.K., Chow, K.W., Lai, A.Y., Mak, N.K., Sze, J.C., Tsang, S.M., 2017. The effects of therapeutic hip exercise with abdominal core activation on recruitment of the hip muscles. BMC Musculoskelet. Disord. 18, 313.

Chepeha, J.C., Magee, D.J., Bouliane, M., Sheps, D., Beaupre, L., 2018. Effectiveness of a posterior shoulder stretching program on university-level overhead athletes: randomized controlled trial. Clin. J. Sport Med. 28, 146–152.

Choi, D., Cole, K.J., Goodpaster, B.H., Fink, W.J., Costill, D.L., 1994. Effect of passive and active recovery on the resynthesis of muscle glycogen. Med. Sci. Sports Exerc. 26, 992–996.

Coetsee, C., Terblanche, E., 2017. Cerebral oxygenation during cortical activation: the differential influence of three exercise training modalities. A randomized controlled trial. Eur. J. Appl. Physiol. 117, 1617–1627.

Degoutte, F., Jouanel, P., Filaire, E., 2003. Energy demands during a judo match and recovery. Br. J. Sports Med. 37, 245–249.

Di Blasio, A, Izzicupo, P, Tacconi, L, Di Santo, S, Leogrande, M, Bucci, I, Ripari, P, Di Baldassarre, A & Napolitano, G. (2016). Acute and delayed effects of high intensity interval resistance training organization on cortisol and testosterone production. J. Sports Med. Phys. Fitness 56, 192–199.

Durrer, C., Francois, M., Neudorf, H., Little, J.P., 2017. Acute high-intensity interval exercise reduces human monocyte Toll-like receptor 2 expression in type 2 diabetes. Am. J. Physiol. Regul. Integr. Comp. Physiol. 312, R529–R538.

Edge, J., Eynon, N., McKenna, M.J., Goodman, C.A., Harris, R.C., Bishop, D.J., 2013. Altering the rest interval during high-intensity interval training does not affect muscle or performance adaptations. Exp. Physiol. 98, 481–490.

Egan-Shuttler, J.D., Edmonds, R., Eddy, C., O'Neill, V., Ives, S.J., 2017. The effect of concurrent plyometric training versus submaximal aerobic cycling on rowing economy, peak power, and performance in male high school rowers. Sports Med. Open 3, 7.

Eliakim, A., Brasel, J.A., Barstow, T.J., Mohan, S., Cooper, D.M., 1998. Peak oxygen uptake, muscle volume, and the growth hormone-insulin-like growth factor-I axis in adolescent males. Med. Sci. Sports Exerc. 30, 512–517.

Ellingsen, O., Halle, M., Conraads, V., Stoylen, A., Dalen, H., Delagardelle, C., Larsen, A.I., Hole, T., Mezzani, A., Van Craenenbroeck, E.M., Videm, V., Beckers, P., Christle, J.W., Winzer, E., Mangner, N., Woitek, F., Hollriegel, R., Pressler, A., Monk-Hansen, T., Snoer, M., Feiereisen, P., Valborgland, T., Kjekshus, J., Hambrecht, R., Gielen, S., Karlsen, T., Prescott, E., Linke, A., Group, SHFS, 2017. High-intensity interval training in patients with heart failure with reduced ejection fraction. Circulation 135, 839–849.

Esteve-Lanao, J., San Juan, A.F., Earnest, C.P., Foster, C., Lucia, A., 2005. How do endurance runners actually train? Relationship with competition performance. Med. Sci. Sports Exerc. 37, 496–504.

Esteve-Lanao, J., Rhea, M.R., Fleck, S.J., Lucia, A., 2008. Running-specific, periodized strength training attenuates loss of stride length during intense endurance running. J. Strength Cond. Res. 22, 1176–1183.
Evans, M., Cogan, K.E., Egan, B., 2017. Metabolism of ketone bodies during exercise and training: physiological basis for exogenous supplementation. J. Physiol. 595, 2857–2871.
Faigenbaum, A.D., Myer, G.D., 2010. Resistance training among young athletes: safety, efficacy and injury prevention effects. Br. J. Sports Med. 44, 56–63.
Fessi, M.S., Zarrouk, N., Di Salvo, V., Filetti, C., Barker, A.R., Moalla, W., 2016. Effects of tapering on physical match activities in professional soccer players. J. Sports Sci. 34, 2189–2194.
Figueiredo, V.C., Caldow, M.K., Massie, V., Markworth, J.F., Cameron-Smith, D., Blazevich, A.J., 2015. Ribosome biogenesis adaptation in resistance training-induced human skeletal muscle hypertrophy. Am. J. Physiol. Endocrinol. Metab. 309, E72–83.
Fournier, P.E., Stalder, J., Mermillod, B., Chantraine, A., 1997. Effects of a 110 kilometers ultra-marathon race on plasma hormone levels. Int. J. Sports Med. 18, 252–256.
Francois, M.E., Durrer, C., Pistawka, K.J., Halperin, F.A., Chang, C., Little, J.P., 2017. Combined interval training and post-exercise nutrition in type 2 diabetes: a randomized control trial. Front. Physiol. 8, 528.
Frost, D.M., Bronson, S., Cronin, J.B., Newton, R.U., 2016. Changes in maximal strength, velocity, and power after 8 weeks of training with pneumatic or free weight resistance. J. Strength Cond. Res. 30, 934–944.
Gavin, T.P., Drew, J.L., Kubik, C.J., Pofahl, W.E., Hickner, R.C., 2007. Acute resistance exercise increases skeletal muscle angiogenic growth factor expression. Acta Physiol. (Oxf.) 191, 139–146.
Gejl, K.D., Hvid, L.G., Frandsen, U., Jensen, K., Sahlin, K., Ortenblad, N., 2014. Muscle glycogen content modifies SR Ca^{2+} release rate in elite endurance athletes. Med. Sci. Sports Exerc. 46, 496–505.
Giovanelli, N., Taboga, P., Rejc, E., Lazzer, S., 2017. Effects of strength, explosive and plyometric training on energy cost of running in ultra-endurance athletes. Eur. J. Sport Sci. 17, 805–813.
Guillou, P., 1989. Interleukin-2 and lymphokine-activated killer cell therapy for gastrointestinal cancer. Acta Chir. Scand. Suppl. 549, 26–30.
Gulpinar, D., Ozer, S.T., Yesilyaprak, S.S., 2017. Effects of rigid and Kinesio taping on shoulder rotation motions, posterior shoulder tightness, and posture in asymptomatic overhead athletes: a randomized controlled trial. J. Sport Rehabil., 1–26.
Harber, M.P., Gallagher, P.M., Creer, A.R., Minchev, K.M., Trappe, S.W., 2004. Single muscle fiber contractile properties during a competitive season in male runners. Am. J. Physiol. Regul. Integr. Comp. Physiol. 287, R1124–1131.
Hickson, R.C., 1980. Interference of strength development by simultaneously training for strength and endurance. Eur. J. Appl. Physiol. Occup. Physiol. 45, 255–263.
Hickson, R.C., Foster, C., Pollock, M.L., Galassi, T.M., Rich, S., 1985. Reduced training intensities and loss of aerobic power, endurance, and cardiac growth. J. Appl. Physiol. 58, 492–499.
Hofmann, P., Tschakert, G., 2017. Intensity- and duration-based options to regulate endurance training. Front. Physiol. 8, 337.
Horschig, A.D., Neff, T.E., Serrano, A.J., 2014. Utilization of autoregulatory progressive resistance exercise in transitional rehabilitation periodization of a high school football-player following anterior cruciate ligament reconstruction: a case report. Int. J. Sports Phys. Ther. 9, 691–698.
Iaia, F.M., Hellsten, Y., Nielsen, J.J., Fernstrom, M., Sahlin, K., Bangsbo, J., 2009. Four weeks of speed endurance training reduces energy expenditure during exercise and maintains muscle oxidative capacity despite a reduction in training volume. J. Appl. Physiol. 106, 73–80.

Inoki, K., Zhu, T., Guan, K.L., 2003. TSC2 mediates cellular energy response to control cell growth and survival. Cell 115, 577–590.
Inoue, D.S., De Mello, M.T., Foschini, D., Lira, F.S., De Piano Ganen, A., Da Silveira Campos, R.M., De Lima Sanches, P., Silva, P.L., Corgosinho, F.C., Rossi, F.E., Tufik, S., Damaso, A.R., 2015. Linear and undulating periodized strength plus aerobic training promote similar benefits and lead to improvement of insulin resistance on obese adolescents. J. Diabetes Complicat. 29, 258–264.
Issurin, V.B., 2016. Benefits and limitations of block periodized training approaches to athletes' preparation: a review. Sports Med. 46, 329–338.
Jia, J., Kang, L., Li, S., Geng, D., Fan, P., Wang, L., Cui, H., 2013. Amelioratory effects of testosterone treatment on cognitive performance deficits induced by soluble Abeta1-42 oligomers injected into the hippocampus. Horm. Behav. 64, 477–486.
Joanisse, S., McKay, B.R., Nederveen, J.P., Scribbans, T.D., Gurd, B.J., Gillen, J.B., Gibala, M.J., Tarnopolsky, M., Parise, G., 2015. Satellite cell activity, without expansion, after nonhypertrophic stimuli. Am. J. Physiol. Regul. Integr. Comp. Physiol. 309, R1101–1111.
Johnson, B.A., Salzberg, C.L., Stevenson, D.A., 2011. A systematic review: plyometric training programs for young children. J. Strength Cond. Res. 25, 2623–2633.
Kao, S.C., Westfall, D.R., Soneson, J., Gurd, B., Hillman, C.H., 2017. Comparison of the acute effects of high-intensity interval training and continuous aerobic walking on inhibitory control. Psychophysiology 54, 1335–1345.
Keller, P., Vollaard, N.B., Gustafsson, T., Gallagher, I.J., Sundberg, C.J., Rankinen, T., Britton, S.L., Bouchard, C., Koch, L.G., Timmons, J.A., 2011. A transcriptional map of the impact of endurance exercise training on skeletal muscle phenotype. J. Appl. Physiol. 110, 46–59.
Kelly, D.M., Jones, T.H., 2014. Testosterone and cardiovascular risk in men. Front. Horm. Res. 43, 1–20.
Kilian, Y., Wehmeier, U.F., Wahl, P., Mester, J., Hilberg, T., Sperlich, B., 2016. Acute response of circulating vascular regulating microRNAs during and after high-intensity and high-volume cycling in children. Front. Physiol. 7, 92.
Kohn, T.A., Essen-Gustavsson, B., Myburgh, K.H., 2011. Specific muscle adaptations in type II fibers after high-intensity interval training of well-trained runners. Scand. J. Med. Sci. Sports 21, 765–772.
Koltai, E., Bori, Z., Chabert, C., Dubouchaud, H., Naito, H., Machida, S., Davies, K.J., Murlasits, Z., Fry, A.C., Boldogh, I., Radak, Z., 2017. SIRT1 may play a crucial role in overload-induced hypertrophy of skeletal muscle. J. Physiol. 595, 3361–3376.
Kraemer, W.J., Hakkinen, K., Newton, R.U., McCormick, M., Nindl, B.C., Volek, J.S., Gotshalk, L.A., Fleck, S.J., Campbell, W.W., Gordon, S.E., Farrell, P.A., Evans, W.J., 1998. Acute hormonal responses to heavy resistance exercise in younger and older men. Eur. J. Appl. Physiol. Occup. Physiol. 77, 206–211.
Kraemer, W.J., Hakkinen, K., Triplett-Mcbride, N.T., Fry, A.C., Koziris, L.P., Ratamess, N.A., Bauer, J.E., Volek, J.S., McConnell, T., Newton, R.U., Gordon, S.E., Cummings, D., Hauth, J., Pullo, F., Lynch, J.M., Fleck, S.J., Mazzetti, S.A., Knuttgen, H.G., 2003. Physiological changes with periodized resistance training in women tennis players. Med. Sci. Sports Exerc. 35, 157–168.
Krustrup, P., Ortenblad, N., Nielsen, J., Nybo, L., Gunnarsson, T.P., Iaia, F.M., Madsen, K., Stephens, F., Greenhaff, P., Bangsbo, J., 2011. Maximal voluntary contraction force, SR function and glycogen resynthesis during the first 72 h after a high-level competitive soccer game. Eur. J. Appl. Physiol. 111, 2987–2995.
Lake, J.P., Lauder, M.A., 2012. Kettlebell swing training improves maximal and explosive strength. J. Strength Cond. Res. 26, 2228–2233.
Larsen, F.J., Schiffer, T.A., Ortenblad, N., Zinner, C., Morales-Alamo, D., Willis, S.J., Calbet, J.A., Holmberg, H.C., Boushel, R., 2016. High-intensity sprint training inhibits mitochondrial respiration through aconitase inactivation. FASEB J. 30, 417–427.

Lauber, B., Franke, S., Taube, W., Gollhofer, A., 2017. The effects of a single bout of exercise on motor memory interference in the trained and untrained hemisphere. Neuroscience 347, 57–64.

Leiter, J.R., Peeler, J., Anderson, J.E., 2011. Exercise-induced muscle growth is muscle-specific and age-dependent. Muscle Nerve 43, 828–838.

Lesinski, M., Prieske, O., Granacher, U., 2016. Effects and dose-response relationships of resistance training on physical performance in youth athletes: a systematic review and meta-analysis. Br. J. Sports Med. 50, 781–795.

Linnamo, V., Newton, R.U., Hakkinen, K., Komi, P.V., Davie, A., McGuigan, M., Triplett-McBride, T., 2000. Neuromuscular responses to explosive and heavy resistance loading. J. Electromyogr. Kinesiol. 10, 417–424.

Little, J.P., Safdar, A., Wilkin, G.P., Tarnopolsky, M.A., Gibala, M.J., 2010. A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: potential mechanisms. J. Physiol. 588, 1011–1022.

Loturco, I., Nakamura, F.Y., Kobal, R., Gil, S., Pivetti, B., Pereira, L.A., Roschel, H., 2016. Traditional periodization versus optimum training load applied to soccer players: effects on neuromuscular abilities. Int. J. Sports Med. 37, 1051–1059.

Lundby, C., Robach, P., 2015. Performance enhancement: what are the physiological limits? Physiology 30, 282–292.

MacDougall, J.D., Hicks, A.L., MacDonald, J.R., McKelvie, R.S., Green, H.J., Smith, K.M., 1998. Muscle performance and enzymatic adaptations to sprint interval training. J. Appl. Physiol. 84, 2138–2142.

Mangine, G.T., Hoffman, J.R., Gonzalez, A.M., Townsend, J.R., Wells, A.J., Jajtner, A.R., Beyer, K.S., Boone, C.H., Wang, R., Miramonti, A.A., LaMonica, M.B., Fukuda, D.H., Witta, E.L., Ratamess, N.A., Stout, J.R., 2017. Exercise-induced hormone elevations are related to muscle growth. J. Strength Cond. Res. 31, 45–53.

McConell, G.K., Costill, D.L., Widrick, J.J., Hickey, M.S., Tanaka, H., Gastin, P.B., 1993. Reduced training volume and intensity maintain aerobic capacity but not performance in distance runners. Int. J. Sports Med. 14, 33–37.

McKendry, J., Perez-Lopez, A., McLeod, M., Luo, D., Dent, J.R., Smeuninx, B., Yu, J., Taylor, A.E., Philp, A., Breen, L., 2016. Short inter-set rest blunts resistance exercise-induced increases in myofibrillar protein synthesis and intracellular signalling in young males. Exp. Physiol. 101, 866–882.

Milia, R., Roberto, S., Pinna, M., Palazzolo, G., Sanna, I., Omeri, M., Piredda, S., Migliaccio, G., Concu, A., Crisafulli, A., 2014. Physiological responses and energy expenditure during competitive fencing. Appl. Physiol. Nutr. Metab. 39, 324–328.

Millet, G.Y., Banfi, J.C., Kerherve, H., Morin, J.B., Vincent, L., Estrade, C., Geyssant, A., Feasson, L., 2011. Physiological and biological factors associated with a 24 h treadmill ultra-marathon performance. Scand. J. Med. Sci. Sports 21, 54–61.

Mourtzakis, M., Saltin, B., Graham, T., Pilegaard, H., 2006. Carbohydrate metabolism during prolonged exercise and recovery: interactions between pyruvate dehydrogenase, fatty acids, and amino acids. J. Appl. Physiol. 100, 1822–1830.

Mujika, I., Goya, A., Padilla, S., Grijalba, A., Gorostiaga, E., Ibanez, J., 2000. Physiological responses to a 6-d taper in middle-distance runners: influence of training intensity and volume. Med. Sci. Sports Exerc. 32, 511–517.

Munoz, I., Seiler, S., Alcocer, A., Carr, N., Esteve-Lanao, J., 2015. Specific intensity for peaking: is race pace the best option? Asian J. Sports Med. 6, e24900.

Myers, A.M., Beam, N.W., Fakhoury, J.D., 2017. Resistance training for children and adolescents. Transl. Pediatr. 6, 137–143.

Nakajima, T., Yasuda, T., Koide, S., Yamasoba, T., Obi, S., Toyoda, S., Sato, Y., Inoue, T., Kano, Y., 2016. Repetitive restriction of muscle blood flow enhances mTOR signaling pathways in a rat model. Heart Vessel. 31, 1685–1695.

O'Leary, T.J., Collett, J., Howells, K., Morris, M.G., 2017. Endurance capacity and neuromuscular fatigue following high- vs moderate-intensity endurance training: a randomized trial. Scand. J. Med. Sci. Sports, 27, 1648–1661.
O'Neal, E.K., Davis, B.A., Thigpen, L.K., Caufield, C.R., Horton, A.D., McIntosh, J.R., 2012. Runners greatly underestimate sweat losses before and after a 1-hr summer run. Int. J. Sport Nutr. Exerc. Metab. 22, 353–362.
Papacosta, E., Gleeson, M., Nassis, G.P., 2013. Salivary hormones, IgA, and performance during intense training and tapering in judo athletes. J. Strength Cond. Res. 27, 2569–2580.
Pope Jr., H.G., Amiaz, R., Brennan, B.P., Orr, G., Weiser, M., Kelly, J.F., Kanayama, G., Siegel, A., Hudson, J.I., Seidman, S.N., 2010. Parallel-group placebo-controlled trial of testosterone gel in men with major depressive disorder displaying an incomplete response to standard antidepressant treatment. J. Clin. Psychopharmacol. 30, 126–134.
Radak, Z., Apor, P., Pucsok, J., Berkes, I., Ogonovszky, H., Pavlik, G., Nakamoto, H., Goto, S., 2003. Marathon running alters the DNA base excision repair in human skeletal muscle. Life Sci. 72, 1627–1633.
Radak, Z., Chung, H.Y., Goto, S., 2008. Systemic adaptation to oxidative challenge induced by regular exercise. Free Radic. Biol. Med. 44, 153–159.
Ramirez-Campillo, R., Alvarez, C., Henriquez-Olguin, C., Baez, E.B., Martinez, C., Andrade, D.C., Izquierdo, M., 2014. Effects of plyometric training on endurance and explosive strength performance in competitive middle- and long-distance runners. J. Strength Cond. Res. 28, 97–104.
Ramos, J.S., Dalleck, L.C., Tjonna, A.E., Beetham, K.S., Coombes, J.S., 2015. The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: a systematic review and meta-analysis. Sports Med. 45, 679–692.
Ribeiro, P.A., Boidin, M., Juneau, M., Nigam, A., Gayda, M., 2017. High-intensity interval training in patients with coronary heart disease: prescription models and perspectives. Ann. Phys. Rehabil. Med. 60, 50–57.
Robergs, R.A., Pearson, D.R., Costill, D.L., Fink, W.J., Pascoe, D.D., Benedict, M.A., Lambert, C.P., Zachweija, J.J., 1991. Muscle glycogenolysis during differing intensities of weight-resistance exercise. J. Appl. Physiol. 70, 1700–1706.
Robertson, S.J., Joyce, D.G., 2015. Informing in-season tactical periodisation in team sport: development of a match difficulty index for Super Rugby. J. Sports Sci. 33, 99–107.
Ronnestad, B.R., Ellefsen, S., Nygaard, H., Zacharoff, E.E., Vikmoen, O., Hansen, J., Hallen, J., 2014. Effects of 12 weeks of block periodization on performance and performance indices in well-trained cyclists. Scand. J. Med. Sci. Sports 24, 327–335.
Ronnestad, B.R., Hansen, J., Thyli, V., Bakken, T.A., Sandbakk, O., 2016. 5-week block periodization increases aerobic power in elite cross-country skiers. Scand. J. Med. Sci. Sports 26, 140–146.
Rooijackers, H.M., Wiegers, E.C., van der Graaf, M., Thijssen, D.H., Kessels, R.P.C., Tack, C.J., de Galan, B.E., 2017. A single bout of high-intensity interval training reduces awareness of subsequent hypoglycemia in patients with type 1 diabetes. Diabetes 66, 1990–1998.
Rowland, T.W., Boyajian, A., 1995. Aerobic response to endurance exercise training in children. Pediatrics 96, 654–658.
Santos-Concejero, J., Billaut, F., Grobler, L., Olivan, J., Noakes, T.D., Tucker, R., 2017. Brain oxygenation declines in elite Kenyan runners during a maximal interval training session. Eur. J. Appl. Physiol. 117, 1017–1024.
Saraslanidis, P.J., Manetzis, C.G., Tsalis, G.A., Zafeiridis, A.S., Mougios, V.G., Kellis, S.E., 2009. Biochemical evaluation of running workouts used in training for the 400-m sprint. J. Strength Cond. Res. 23, 2266–2271.

Scalzo, R.L., Peltonen, G.L., Binns, S.E., Shankaran, M., Giordano, G.R., Hartley, D.A., Klochak, A.L., Lonac, M.C., Paris, H.L., Szallar, S.E., Wood, L.M., Peelor 3rd, F.F., Holmes, W.E., Hellerstein, M.K., Bell, C., Hamilton, K.L., Miller, B.F., 2014. Greater muscle protein synthesis and mitochondrial biogenesis in males compared with females during sprint interval training. FASEB J. 28, 2705–2714.

Schumann, M., Eklund, D., Taipale, R.S., Nyman, K., Kraemer, W.J., Hakkinen, A., Izquierdo, M., Hakkinen, K., 2013. Acute neuromuscular and endocrine responses and recovery to single-session combined endurance and strength loadings: "order effect" in untrained young men. J. Strength Cond. Res. 27, 421–433.

Scudese, E., Simao, R., Senna, G., Vingren, J.L., Willardson, J.M., Baffi, M., Miranda, H., 2016. Long rest interval promotes durable testosterone responses in high-intensity bench press. J. Strength Cond. Res. 30, 1275–1286.

Shankaran, M., King, C.L., Angel, T.E., Holmes, W.E., Li, K.W., Colangelo, M., Price, J.C., Turner, S.M., Bell, C., Hamilton, K.L., Miller, B.F., Hellerstein, M.K., 2016. Circulating protein synthesis rates reveal skeletal muscle proteome dynamics. J. Clin. Invest. 126, 288–302.

Shepley, B., MacDougall, J.D., Cipriano, N., Sutton, J.R., Tarnopolsky, M.A., Coates, G., 1992. Physiological effects of tapering in highly trained athletes. J. Appl. Physiol. 72, 706–711.

Skovgaard, C., Almquist, N.W., Bangsbo, J., 2018. The effect of repeated periods of speed endurance training on performance, running economy, and muscle adaptations. Scand. J. Med. Sci. Sports, 28, 381–391.

Slawinski, J., Demarle, A., Koralsztein, J.P., Billat, V., 2001. Effect of supra-lactate threshold training on the relationship between mechanical stride descriptors and aerobic energy cost in trained runners. Arch. Physiol. Biochem. 109, 110–116.

Tabata, I., Nishimura, K., Kouzaki, M., Hirai, Y., Ogita, F., Miyachi, M., Yamamoto, K., 1996. Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO_2max. Med. Sci. Sports Exerc. 28, 1327–1330.

Takagi, S., Kime, R., Niwayama, M., Hirayama, K., Sakamoto, S., 2017. Effects of 8 weeks' training on systemic and muscle oxygen dynamics in university rugby players. Adv. Exp. Med. Biol. 977, 43–49.

Talanian, J.L., Holloway, G.P., Snook, L.A., Heigenhauser, G.J., Bonen, A., Spriet, L.L., 2010. Exercise training increases sarcolemmal and mitochondrial fatty acid transport proteins in human skeletal muscle. Am. J. Phys. Endocrinol. Metab. 299, E180–188.

Terada, S., Tabata, I., 2004. Effects of acute bouts of running and swimming exercise on PGC-1alpha protein expression in rat epitrochlearis and soleus muscle. Am. J. Phys. Endocrinol. Metab. 286, E208–216.

Thomson, D.M., Gordon, S.E., 2005. Diminished overload-induced hypertrophy in aged fast-twitch skeletal muscle is associated with AMPK hyperphosphorylation. J. Appl. Physiol. 98, 557–564.

Tillin, N.A., Pain, M.T., Folland, J.P., 2012. Short-term training for explosive strength causes neural and mechanical adaptations. Exp. Physiol. 97, 630–641.

Tonnessen, E., Sylta, O., Haugen, T.A., Hem, E., Svendsen, I.S., Seiler, S., 2014. The road to gold: training and peaking characteristics in the year prior to a gold medal endurance performance. PLoS One 9, e101796.

Tourinho Filho, H., Pires, M., Puggina, E.F., Papoti, M., Barbieri, R., Martinelli Jr., C.E., 2017. Serum IGF-I, IGFBP-3 and ALS concentrations and physical performance in young swimmers during a training season. Growth Hormon. IGF Res. 32, 49–54.

van Loon, L.J., Greenhaff, P.L., Constantin-Teodosiu, D., Saris, W.H., Wagenmakers, A.J., 2001. The effects of increasing exercise intensity on muscle fuel utilisation in humans. J. Physiol. 536, 295–304.

Vikmoen, O., Ellefsen, S., Troen, O., Hollan, I., Hanestadhaugen, M., Raastad, T., Ronnestad, B.R., 2016. Strength training improves cycling performance, fractional utilization of VO_2max and cycling economy in female cyclists. Scand. J. Med. Sci. Sports 26, 384–396.
Vuorimaa, T., Ahotupa, M., Hakkinen, K., Vasankari, T., 2008. Different hormonal response to continuous and intermittent exercise in middle-distance and marathon runners. Scand. J. Med. Sci. Sports 18, 565–572.
Wahl, P., Mathes, S., Achtzehn, S., Bloch, W., Mester, J., 2014. Active vs. passive recovery during high-intensity training influences hormonal response. Int. J. Sports Med. 35, 583–589.
Walker, S., Hulmi, J.J., Wernbom, M., Nyman, K., Kraemer, W.J., Ahtiainen, J.P., Hakkinen, K., 2013. Variable resistance training promotes greater fatigue resistance but not hypertrophy versus constant resistance training. Eur. J. Appl. Physiol. 113, 2233–2244.
Wang, E., Solli, G.S., Nyberg, S.K., Hoff, J., Helgerud, J., 2012. Stroke volume does not plateau in female endurance athletes. Int. J. Sports Med. 33, 734–739.
Weiner, R.B., DeLuca, J.R., Wang, F., Lin, J., Wasfy, M.M., Berkstresser, B., Stohr, E., Shave, R., Lewis, G.D., Hutter Jr., A.M., Picard, M.H., Baggish, A.L., 2015. Exercise-induced left ventricular remodeling among competitive athletes: a phasic phenomenon. Circ. Cardiovasc. Imaging 8.
Widrick, J.J., Stelzer, J.E., Shoepe, T.C., Garner, D.P., 2002. Functional properties of human muscle fibers after short-term resistance exercise training. Am. J. Physiol. Regul. Integr. Comp. Physiol. 283, R408–416.
Yu, M., Blomstrand, E., Chibalin, A.V., Krook, A., Zierath, J.R., 2001. Marathon running increases ERK1/2 and p38 MAP kinase signalling to downstream targets in human skeletal muscle. J. Physiol. 536, 273–282.

BIBLIOGRAPHY

Alentorn-Geli, E., Myer, G.D., Silvers, H.J., Samitier, G., Romero, D., Lazaro-Haro, C., Cugat, R., 2009. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: Mechanisms of injury and underlying risk factors. Knee Surg. Sports Traumatol. Arthrosc. 17, 705–729.

Alves, C.R., Borelli, M.T., Paineli Vde, S., Azevedo Rde, A., Borelli, C.C., Lancha Junior, A.H., Gualano, B., Artioli, G.G., 2015. Development of a specific anaerobic field test for aerobic gymnastics. PLoS One 10, e0123115.

Baguet, A., Everaert, I., Hespel, P., Petrovic, M., Achten, E., Derave, W., 2011. A new method for non-invasive estimation of human muscle fiber type composition. PLoS One 6, e21956.

Bampouras, T.M., Marrin, K., 2009. Comparison of two anaerobic water polo-specific tests with the Wingate test. J. Strength Cond. Res. 23, 336–340.

Bangsbo, J., Iaia, F.M., Krustrup, P., 2008. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. Sports Med. 38, 37–51.

Block, G.E., 1970. Successful extended hemipelvectomy for "inoperable" chondrosarcoma of the pelvis. Surg. Clin. North Am. 50, 985–997.

Bohannon, R.W., 2008. Hand-grip dynamometry predicts future outcomes in aging adults. J. Geriatr. Phys. Ther. 31, 3–10.

Chino, K., Saito, Y., Matsumoto, S., Ikeda, T., Yanagawa, Y., 2015. Investigation of exercise intensity during a freestyle wrestling match. J. Sports Med. Phys. Fitness 55, 290–296.

Cooper, C.B., Dolezal, B.A., Neufeld, E.V., Shieh, P., Jenner, J.R., Riley, M., 2017. Exercise responses in patients with chronically high creatine kinase levels. Muscle Nerve 56, 264–270.

Dallinga, J.M., Benjaminse, A., Lemmink, K.A., 2012. Which screening tools can predict injury to the lower extremities in team sports?: a systematic review. Sports Med. 42, 791–815.

De Paz, J.A., Villa, J.G., Lopez, P., Gonzalez-Gallego, J., 1995. Effects of long-distance running on serum bilirubin. Med. Sci. Sports Exerc. 27, 1590–1594.

Dotan, R., Bar-Or, O., 1980. Climatic heat stress and performance in the Wingate anaerobic test. Eur. J. Appl. Physiol. Occup. Physiol. 44, 237–243.

Ellefsen, S., Vikmoen, O., Zacharoff, E., Rauk, I., Slettalokken, G., Hammarstrom, D., Strand, T.A., Whist, J.E., Hanestadhaugen, M., Vegge, G., Fagernes, C.E., Nygaard, H., Hollan, I., Ronnestad, B.R., 2014. Reliable determination of training-induced alterations in muscle fiber composition in human skeletal muscle using quantitative polymerase chain reaction. Scand. J. Med. Sci. Sports 24, e332–342.

Ellenbecker, T.S., Cools, A., 2010. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. Br. J. Sports Med. 44, 319–327.

Erickson, B.J., Frank, R.M., Harris, J.D., Mall, N., Romeo, A.A., 2015. The influence of humeral head inclination in reverse total shoulder arthroplasty: a systematic review. J. Shoulder Elb. Surg. 24, 988–993.

Essendrop, M., Maul, I., Laubli, T., Riihimaki, H., Schibye, B., 2002. Measures of low back function: a review of reproducibility studies. Clin. Biomech. (Bristol, Avon) 17, 235–249.

Fatouros, I.G., Destouni, A., Margonis, K., Jamurtas, A.Z., Vrettou, C., Kouretas, D., Mastorakos, G., Mitrakou, A., Taxildaris, K., Kanavakis, E., Papassotiriou, I., 2006. Cell-free plasma DNA as a novel marker of aseptic inflammation severity related to exercise overtraining. Clin. Chem. 52, 1820–1824.

Flotum, L.A., Ottesen, L.S., Krustrup, P., Mohr, M., 2016. Evaluating a nationwide recreational football intervention: recruitment, attendance, adherence, exercise intensity, and health effects. Biomed. Res. Int. 2016, 7231545.

Garcia-Pallares, J., Lopez-Gullon, J.M., Muriel, X., Diaz, A., Izquierdo, M., 2011. Physical fitness factors to predict male Olympic wrestling performance. Eur. J. Appl. Physiol. 111, 1747–1758.

Golle, K., Muehlbauer, T., Wick, D., Granacher, U., 2015. Physical fitness percentiles of German children aged 9–12 years: findings from a longitudinal study. PLoS One 10, e0142393.
Gollnick, P.D., Armstrong, R.B., Saubert, C.W., Piehl, K., Saltin, B., 1972. Enzyme activity and fiber composition in skeletal muscle of untrained and trained men. J. Appl. Physiol. 33, 312–319.
Gollnick, P.D., Armstrong, R.B., Saltin, B., Saubert, C.W., Sembrowich, W.L., Shepherd, R.E., 1973. Effect of training on enzyme activity and fiber composition of human skeletal muscle. J. Appl. Physiol. 34, 107–111.
Hawley, J.A., Williams, M.M., Vickovic, M.M., Handcock, P.J., 1992. Muscle power predicts freestyle swimming performance. Br. J. Sports Med. 26, 151–155.
Hofman, N., Orie, J., Hoozemans, M.J., Foster, C., de Koning, J.J., 2017. Wingate test is a strong predictor of 1500 m performance in elite speed skaters. Int. J. Sports Physiol. Perform, 1–17.
Iaia, F.M., Thomassen, M., Kolding, H., Gunnarsson, T., Wendell, J., Rostgaard, T., Nordsborg, N., Krustrup, P., Nybo, L., Hellsten, Y., Bangsbo, J., 2008. Reduced volume but increased training intensity elevates muscle Na+-K+ pump alpha1-subunit and NHE1 expression as well as short-term work capacity in humans. Am. J. Physiol. Regul. Integr. Comp. Physiol. 294, R966–974.
Jandacka, D., Uchytil, J., 2011. Optimal load maximizes the mean mechanical power output during upper extremity exercise in highly trained soccer players. J. Strength Cond. Res. 25, 2764–2772.
Jindal, P., Narayan, A., Ganesan, S., MacDermid, J.C., 2016. Muscle strength differences in healthy young adults with and without generalized joint hypermobility: a cross-sectional study. BMC Sports Sci. Med. Rehabil. 8, 12.
Kevern, M.A., Beecher, M., Rao, S., 2014. Reliability of measurement of glenohumeral internal rotation, external rotation, and total arc of motion in 3 test positions. J. Athl. Train. 49, 640–646.
Kuno, S., Katsuta, S., Inouye, T., Anno, I., Matsumoto, K., Akisada, M., 1988. Relationship between MR relaxation time and muscle fiber composition. Radiology 169, 567–568.
Legaz-Arrese, A., Munguia-Izquierdo, D., Carranza-Garcia, L.E., Torres-Davila, C.G., 2011. Validity of the Wingate anaerobic test for the evaluation of elite runners. J. Strength Cond. Res. 25, 819–824.
Lozano de Luaces, V., Espias Gomez, A., Murtra Ferre, J., Ruano Gil, D., 1988. Alopecia areata: review and presentation of some clinical cases. Av. Odontoestomatol. 4, 273–279.
Malliaropoulos, N., Kakoura, L., Tsitas, K., Christodoulou, D., Siozos, A., Malliaras, P., Maffulli, N., 2015. Active knee range of motion assessment in elite track and field athletes: normative values. Muscles Ligaments Tendons J. 5, 203–207.
Martin, H.D., Shears, S.A., Palmer, I.J., 2010. Evaluation of the hip. Sports Med. Arthrosc. 18, 63–75.
Mayorga-Vega, D., Merino-Marban, R., Viciana, J., 2014. Criterion-related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: a meta-analysis. J. Sports Sci. Med. 13, 1–14.
Munoz-Lopez, M., Marchante, D., Cano-Ruiz, M.A., Chicharro, J.L., Balsalobre-Fernandez, C., 2017. Load, force and power-velocity relationships in the prone pull-up exercise. Int. J. Sports Physiol. Perform, 1–22.
Nagel, D., Seiler, D., Franz, H., Jung, K., 1990. Ultra-long-distance running and the liver. Int. J. Sports Med. 11, 441–445.
Niemela, M., Kangastupa, P., Niemela, O., Bloigu, R., Juvonen, T., 2016. Individual responses in biomarkers of health after marathon and half-marathon running: is age a factor in troponin changes? Scand. J. Clin. Lab. Invest. 76, 575–580.
Raue, U., Trappe, T.A., Estrem, S.T., Qian, H.R., Helvering, L.M., Smith, R.C., Trappe, S., 2012. Transcriptome signature of resistance exercise adaptations: mixed muscle and fiber type specific profiles in young and old adults. J. Appl. Physiol. 112, 1625–1636.

Reiman, M.P., Mather 3rd, R.C., Cook, C.E., 2015. Physical examination tests for hip dysfunction and injury. Br. J. Sports Med. 49, 357–361.

Scheel, M., von Roth, P., Winkler, T., Arampatzis, A., Prokscha, T., Hamm, B., Diederichs, G., 2013. Fiber type characterization in skeletal muscle by diffusion tensor imaging. NMR Biomed. 26, 1220–1224.

Shin, K.A., Park, K.D., Ahn, J., Park, Y., Kim, Y.J., 2016. Comparison of changes in biochemical markers for skeletal muscles, hepatic metabolism, and renal function after three types of long-distance running: observational study. Medicine (Baltimore) 95, e3657.

Simunic, B., Degens, H., Rittweger, J., Narici, M., Mekjavic, I.B., Pisot, R., 2011. Noninvasive estimation of myosin heavy chain composition in human skeletal muscle. Med. Sci. Sports Exerc. 43, 1619–1625.

Stewart, J., Manmathan, G., Wilkinson, P., 2017. Primary prevention of cardiovascular disease: a review of contemporary guidance and literature. JRSM Cardiovasc. Dis. 6. 2048004016687211.

Uth, N., Sorensen, H., Overgaard, K., Pedersen, P.K., 2004. Estimation of VO2max from the ratio between HRmax and HRrest—the heart rate ratio method. Eur. J. Appl. Physiol. 91, 111–115.

Wagner, H., Orwat, M., Hinz, M., Pfusterschmied, J., Bacharach, D.W., von Duvillard, S.P., Muller, E., 2016. Testing game-based performance in team-handball. J. Strength Cond. Res. 30, 2794–2801.

Wanaka, A., Malbon, C.C., Matsumoto, M., Kamada, T., Tohyama, M., 1989. Presence of catecholaminergic axon-terminals containing beta-adrenergic receptor in the periventricular zone of the rat hypothalamus. Brain Res. 479, 190–193.

Zagatto, A.M., Papoti, M., Gobatto, C.A., 2008. Anaerobic capacity may not be determined by critical power model in elite table tennis players. J. Sports Sci. Med. 7, 54–59.