

Cardiovascular and Perceived Exertion Responses to Leisure Trail Hiking

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Abstract

The majority of U.S. adults participate in outdoor recreation, and hiking is a top activity. However, little literature exists in which the physiological responses to trail hiking are detailed. The purposes of this study were to compare cardiovascular and perceived exertion measurements during hiking on an easy rated versus a strenuous trail and to determine the reliability on the easy trail. Volunteers completed two easy hikes in 1 day and 1 strenuously rated trail the next day. Heart rate (HR), systolic blood pressure (SBP), and ratings of perceived exertion (RPE) were recorded. Significant test–retest reliability was observed for HR, SBP, and RPE. The strenuous uphill trail elicited increased HR and RPE compared with the easy trail and the downhill portion. This shows that select cardiovascular and perceived exertion variables have moderate to high test–retest reliability. These results provide evidence that leisure trail hiking likely provides sufficient cardiovascular stimulation to induce beneficial physiological adaptations.

KEYWORDS: heart rate; blood pressure; hike

Only 30.8% of the American population is reported to be at a healthy weight (Office of Disease Prevention and Health Promotion, 2008). The implication of an elevated overweight and obese population puts a strain on health care and overall quality of life and is associated with a number of comorbidities such as type 2 diabetes mellitus, hypercholesterolemia, and hypertension (Must et al., 1999). Because of this, one of the Healthy People 2020 objectives is to increase the proportion of adults who are at a healthy weight to a target of 33.9% (Office of Disease Prevention and Health Promotion, 2008). To meet this goal, organizations such as the American College of Sports Medicine (ACSM; Garber et al., 2011) and the American Heart Association (AHA; Fletcher et al., 1996) have proposed that individuals engage in leisure-time physical activity, including hiking.

According to the National Survey on Recreation and the Environment, 97% of Americans aged 16 years and older participate to some extent in outdoor recreation (Cordell et al., 2005). Recent trends indicate hiking has enjoyed a 194% increase, placing it in the top two performed outdoor activities (Cordell et al., 2005). As more individuals are engaging in hiking outdoors, there is a need to understand the physiological responses that accompany this activity. Some researchers have attempted to simulate the experience in the laboratory (Porcari, Hendrickson, Walter, Terry, & Walsko, 1997; Rodgers, VanHeest, & Schachter, 1995) or have focused specifically on the effects of hiking poles (Duckham, Bassett, Fitzhugh, Swibas, & McMahan, 2009; Jacobson, Caldwell, & Kulling, 1997; Jacobson & Wright, 1998; Knight & Caldwell, 2000). Other researchers have determined the effect of a hiking program at different altitudes in older individuals (Burtscher et al., 2001) or the response to a weeklong trek on low energy intake (Marniemi et al., 1984).

To our knowledge, no investigations have been designed to determine the reliability of field-based physiological measurements in response to leisure trail hiking or to compare these responses to current ACSM recommendations. We hypothesized measures obtained in the field would be reproducible and hiking on a strenuous trail would provide responses of sufficient intensity to compare with ACSM guidelines for minimum aerobic activity. The purposes of this multiphase study were to (1) compare cardiovascular and ratings of perceived exertion measurements during hiking on trails rated easy versus strenuous, (2) compare measurements from the uphill versus downhill component of a strenuous trail, and (3) determine the intraclass correlation reliability of measurements on the easy trail.

Method

Participants

Volunteers ($N_{\text{male}} = 7$, $N_{\text{female}} = 3$) had the following characteristics: age = 25.0 ± 3.4 years, height = 172.9 ± 11.3 cm, and body mass = 71.6 ± 10.8 kg. Prior to involvement in the study, participants provided informed consent that was approved by the institutional review board (protocol #13-092014).

Protocol

To determine test-retest reliability, subjects completed two easy (Class I) rated trail hikes at the set pace of $3.2 \text{ km} \cdot \text{h}^{-1}$ (2 mph), separated by 15-min rest. Altitude was measured at 5,446 ft above sea level (4400 Heat Stress Tracker, Kestrel, Boothwyn, PA). Heart rate (HR) data at the beginning of each hike was not different ($\text{HR}_{\text{easy hike 1}} = 70 \pm 12 \text{ bpm}$, $\text{HR}_{\text{easy hike 2}} = 68 \pm 10 \text{ bpm}$, $t\text{-statistic} = 0.312$, $p = 0.763$), indicating the 15-min rest interval was sufficient for participants to return to resting values. The distance each way was 1.82 km (1.13 miles) at an approximate 0% grade. Measurements of HR, systolic blood pressure (SBP), and diastolic blood pressure (DBP), and ratings of perceived exertion (RPE) were obtained at the beginning and at the end of each hike. HR was self-palpated by participants at the radial artery using a 15-s count. This method of

HR was chosen because measurements could be obtained in the field, and it has been shown to be no different compared to electrocardiogram measurements up to intensities of 70% of the HR maximum (Devan, Lacy, Cortez-Cooper, & Tanaka, 2005). Blood pressure was obtained manually through a stethoscope and sphygmomanometer using the AHA recommended first Kortkoff sound as the systolic measurement and the third Kortkoff sound as the diastolic measurement (Pickering et al., 2005). RPE was obtained using the Borg scale (Borg, 1970), which is a subjective rating of an individual's overall body exertion level and ranges from 6 on the low end (representing minimal physical exertion) to 20 on the high end (representing the maximal level of exertion an individual feels he or she can accomplish). Prior to the study, each participant was provided with information on what the Borg scale represents. Rate pressure product (RPP) was calculated as $(HR \times SBP) \div 100$.

To determine whether differently rated hikes met the ACSM recommendation for daily physical activity, a strenuously rated trail hike (1.13 miles each way, 17.6% grade) was completed separately the following day. The altitude at the beginning of the hike was 5,757 ft above sea level and rose to 6,443 ft at the termination point. Measures were obtained as previously described. HR data at the beginning of each hike was not different ($HR_{\text{strenuous uphill hike}} = 79 \pm 12$ bpm, $HR_{\text{downhill hike}} = 72 \pm 12$ bpm, t -statistic = 1.76, $p = 0.112$), indicating the 15-min rest interval was sufficient for participants to return to baseline.

Statistical Analysis

Data obtained at the end of each hike (i.e., postmeasurements) were compared using one-way repeated measures ANOVAs (easy, strenuous uphill, strenuous downhill) and intraclass correlation coefficients for test-retest analysis and were determined using Statistical Package for the Social Sciences (SPSS, Version 21, IBM Corporation, Armonk, NY) with significance at $p \leq 0.05$. Post hoc analyses were completed using the Tukey LSD option in SPSS when needed.

Results

Hiking Easy Versus Strenuous Rated Trails (Research Question #1)

The strenuous uphill trail elicited significantly increased HR compared with the easy rated trail, $F(2, 18) = 12.85$, $p = 0.006$. See Figure 1. The HR response was equivalent to $53\% \pm 9\%$ of the age-estimated maximal during the strenuous uphill hike and $39\% \pm 5\%$ during the easy rated hike. With regard to the SBP response, no differences were noted between easy and strenuous rated trails, $SBP_{\text{easy hike}} = 122 \pm 8$ mmHg, $SBP_{\text{strenuous uphill hike}} = 124 \pm 10$ mmHg, $F(2, 18) = 1.059$, $p = 0.367$. Similarly, no differences were found in the DBP response between easy and strenuous trails, $DBP_{\text{easy hike}} = 72 \pm 6$ mmHg, $DBP_{\text{strenuous uphill hike}} = 78 \pm 8$ mmHg, $F(2, 18) = 1.488$, $p = 0.252$.

The strenuous uphill hike elicited significantly greater RPP compared with the easy hike, $F(2, 18) = 13.587$, $p = 0.001$. See Figure 2. Subjects perceived the strenuous uphill trail to be significantly more difficult compared with the easy trail, $F(2, 18) = 35.36$, $p = 0.001$. See Figure 3.

Uphill Versus Downhill Component of a Strenuous Trail (Research Question #2)

The strenuous uphill trail produced significantly elevated HR measures compared with the downhill portion, $F(2, 18) = 12.85$, $p = 0.006$. See Figure 1. The downhill portion of the trail elicited an HR response that was $44\% \pm 6\%$ of the age-estimated maximal. Similar to the comparison between the easy and strenuous uphill hikes, the uphill versus downhill portion elicited no differences in the SBP response, $SBP_{\text{strenuous uphill hike}} = 124 \pm 10$ mmHg, $SBP_{\text{strenuous downhill hike}} = 119 \pm 12$ mmHg, $F(2, 18) = 1.059$, $p = 0.367$, or the DBP response, $DBP_{\text{strenuous uphill hike}} = 78 \pm 8$ mmHg, $DBP_{\text{strenuous downhill hike}} = 78 \pm 7$ mmHg, $F(2, 18) = 1.488$, $p = 0.252$.

The strenuous uphill hike elicited significantly greater RPP compared with the downhill portion, $F(2, 18) = 13.587, p = 0.014$. See Figure 2. Additionally, participants perceived the uphill portion of the strenuous trail to be significantly more difficult than the downhill portion of the trail, $F(2, 18) = 35.36, p = 0.001$. See Figure 3.

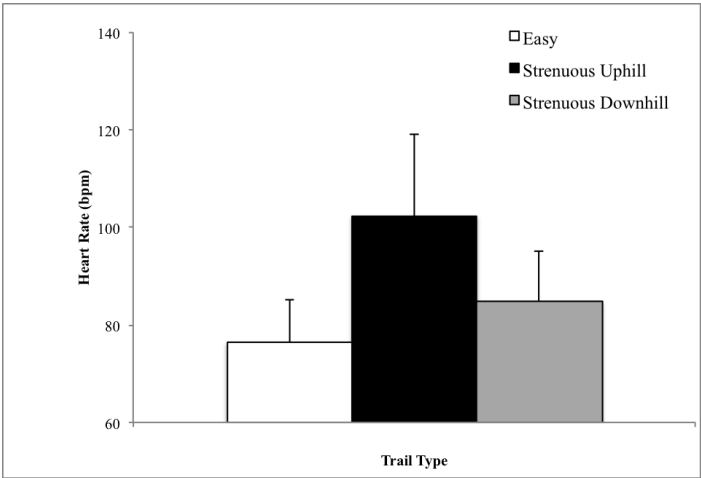


Figure 1. Heart rate response to hiking different trail types.

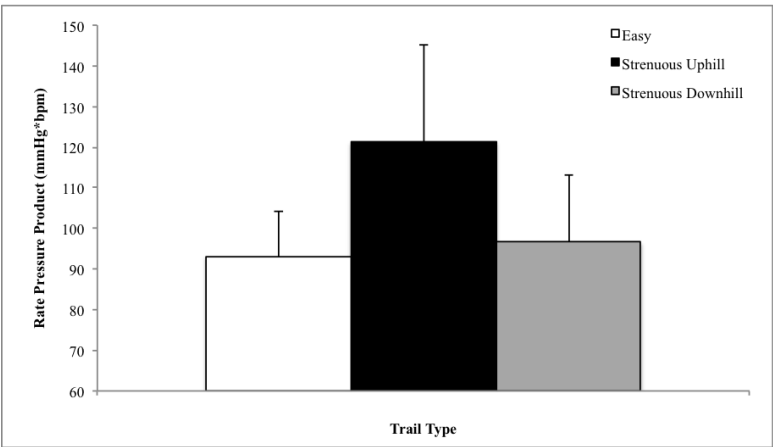


Figure 2. Rate pressure product response to hiking various trail types. RPP was significantly greater during the strenuous uphill hike than during all other conditions at the $p < 0.001$ level.

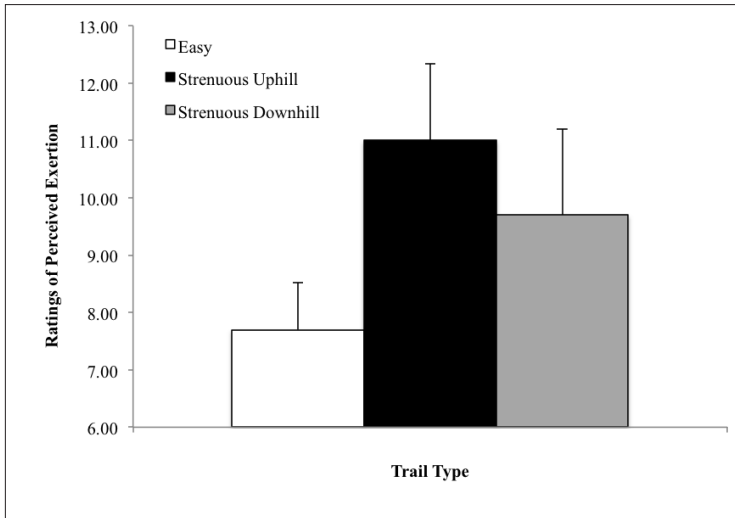


Figure 3. Ratings of perceived exertion to hiking different trail types. RPE was significantly greater during the strenuous uphill hike than during all other conditions at the $p < 0.001$ level. RPE was significantly greater for the strenuous downhill hike than for the easy rated trail at the $p < 0.001$ level.

Intraclass Correlation Reliability of Measurements on the Easy Trail (Research Question #3)

A significant intraclass correlation coefficient ($ICC = 0.59$, $p = 0.03$) was observed for postexercise HR (see Figure 4).

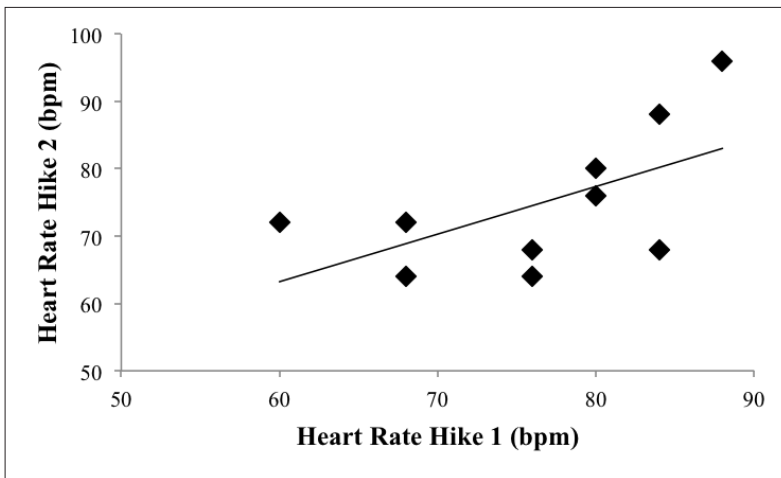


Figure 4. Significant test–retest reliability for radially palpated heart rate on two easy rated trail hikes.

A significant test–retest reliability ($ICC = 0.57, p = 0.04$) was observed for SBP measurements obtained immediately following the easy rated hikes (see Figure 5).

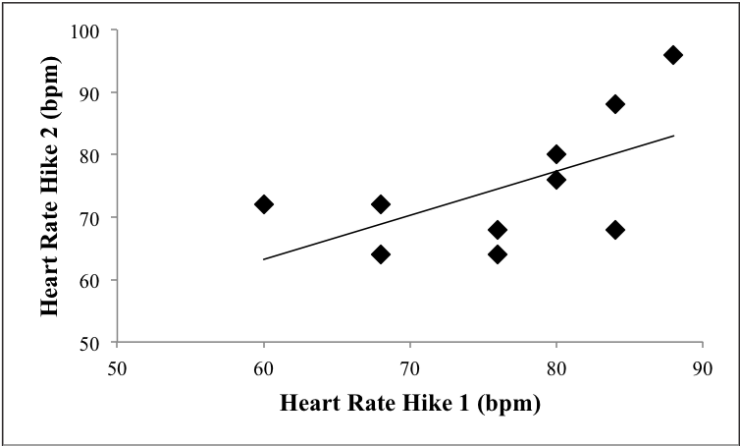


Figure 5. Intraclass correlation for systolic blood pressure on two easy rated trail hikes.

The test–retest reliability coefficient was not significant with regard to DBP ($ICC = 0.05, p = 0.562$) obtained following the easy rated trail hikes or for the calculated RPP ($ICC = 0.43, p = 0.105$). Significant test–retest reliability was observed for postexercise RPE ($ICC = 0.88, p = 0.01$, see Figure 6).

Discussion

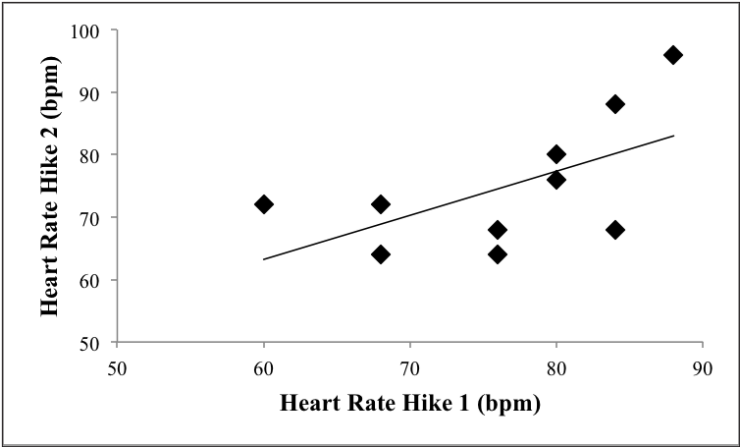


Figure 6. Test–retest reliability for ratings of perceived exertion on two easy rated trail hikes.

The purposes of this investigation were to compare cardiovascular and RPE measurements during hiking on an easy versus strenuous rated trail, to compare measurements from the uphill versus downhill component of a strenuous trail, and to determine the test–retest reliability of measurements on an easy trail. We found that hiking on a strenuous trail with a 17.5% grade

elicited increased HR, RPP, and RPE compared with a trail with an approximate 0% grade, but no differences in SBP or DBP. Additionally, the downhill component of the strenuous trail produced significantly lower HR, RPP, and RPE compared with hiking up the same trail. Finally, we found moderate to high test–retest reliability for HR, SBP, and RPE measures.

In a study in which treadmill exercise was used, Perrey and Fabre (2008) reported increases in HR with a similar percent grade (15%) as used in our hiking study (17.6%;). Subjects were allowed to select their preferred speed and walked at an average of $4.7 \text{ km}\cdot\text{h}^{-1}$ (2.9 mph) at 0% grade, $4.1 \text{ km}\cdot\text{h}^{-1}$ (2.6 mph) during the 15% uphill, and $4.5 \text{ km}\cdot\text{h}^{-1}$ (2.8 mph) during the downhill trail. HR measures were not reported, but it was noted the uphill treadmill walk elicited 36% greater HR compared with the walk at 0% grade and the uphill trail was 52% higher compared with values obtained during the downhill walk (Perrey & Fabre, 2008). Participants in this study walked slower ($3.2 \text{ km}\cdot\text{h}^{-1}$, or 2 mph) than the Perrey and Fabre (2008) participants and had HR values that were 25% higher than the level hike. We found a different response for the negative grade exercise, however, as HR during the uphill portion of the hike was only 17% higher than HR for the return downhill. This can be accounted for partially because of the differences in speed compared with the Perrey and Fabre (2008) investigation, but it is also likely that because of environmental factors, walking on a trail presents varied and increased cardiovascular stimuli than walking on a treadmill alone.

With regard to the SBP response, it is somewhat surprising that no increases were observed on the uphill hike compared with the level and downhill portions. We have previously completed laboratory research comparing cardiovascular responses with various positive, level, and negative grade walking at $4.8 \text{ km}\cdot\text{h}^{-1}$ (3 mph; Navalta, Sedlock, & Park, 2004). In that study, we reported that SBP response was greater when walking on an uphill gradient (5%) compared with level walking and downhill grades ranging from –5% to –20% and that SBP was similar between level walking and all negative grade walking increments (Navalta et al., 2004). These results indicate the SBP response is not greatly affected with level and downhill walking, and this extends to measures obtained following trail hiking.

RPP is clinically used as an indicator of myocardial oxygen demand and can be used to evaluate the amount of stress a particular exercise places on the heart (Gobel, Norstrom, Nelson, Jorgensen, & Wang, 1978). In this investigation, an uphill hike at 17.6% grade produced 23% greater stress on the heart compared with an approximate level hike and 20% more myocardial oxygen demand than walking downhill. This is similar to our laboratory research in which walking at $4.8 \text{ km}\cdot\text{h}^{-1}$ (3 mph) and a 5% grade elicited a 16% increase in RPP compared with 0% grade and a 23% increase compared with –15% grade (Navalta et al., 2004). The current findings indicate hiking at a leisure pace is sufficient to produce acute cardiovascular responses that may prove to be beneficial if applied on a chronic basis.

A secondary purpose of this investigation was to evaluate if leisure trail hiking provided sufficient stimuli to correspond with intensity guidelines set forth by the ACSM (Garber et al., 2011). According to these updated guidelines, it is recommended that adults engage in moderate- and/or vigorous-intensity cardiorespiratory exercise for more than 30-min each day, on 5 or more days each week, for 150 min or more each week (Garber et al., 2011). With the percentage of maximal HR as the indicator for intensity, moderate intensity equates to between 64% and 76% of the maximal HR, whereas vigorous intensity is exercise that elevates HR between 77% and 95% of the maximal HR (Garber et al., 2011). In this study, the strenuous uphill hike increased the HR response to $53\% \pm 9\%$ of the age-estimated maximal, the downhill portion of the hike represented $44\% \pm 6\%$ of HRmax, and the easy rated hike increased HR to $39\% \pm 5\%$ of the age-estimated maximal. For leisure hikers to approach the recommended intensity guidelines, a faster walking pace would be required. Because many participants in this study anecdotally indicated the walking pace was too slow for their preference, subjects in future studies should be allowed to hike at their preferred pace.

In this study, we found leisure hiking was not sufficient to meet the minimum threshold with regard to intensity as indicated by the HR response, but the ACSM extends the recommendations to a combination of moderate- and vigorous-intensity exercise to achieve a total energy expenditure of equal to or greater than 500–1000 MET·min·week⁻¹. Using the ACSM metabolic equations, we determined the easy and downhill hikes were equivalent to 2.53 METs and the uphill hike was equivalent to 4.46 METs. Considering each hike took 34 min to complete, the level and downhill hikes produced 86 MET·min and the uphill hike produced 152 MET·min for each subject. Therefore, it is possible an individual could accumulate enough MET·min each week through leisure hiking to meet the minimum volume threshold to confer benefits similar to individuals completing it through more vigorous modes of exercise. In support of this, Manson et al. (1999) reported that women who walked briskly or hiked outdoors for at least 3 hr per week had the same benefits in reducing the risk of coronary events (30% to 40%) as those who exercised at a vigorous intensity.

The final purpose of this investigation was to provide reliability data on select cardiovascular and perceived exertion measurements in an outdoor setting. To our knowledge, this has not been reported, so these data fill an important gap in the literature. We report for the first time that participants can reliably self-monitor HR measurements following easy rated trail hikes and that perceived exertion levels also represent a reliable self-reported variable. Additionally, SBP measurements obtained by trained personnel at the end of an easy rated hike are also reliable. Whether these reliability data extend to more strenuous hikes remains to be determined, and further investigation is warranted. Nevertheless, an important practical implication of these findings is that emergency medical personnel who are required to take the cardiovascular readings of HR and SBP outdoors on a hiking trail can be assured of the reliability and validity of their measurements.

We acknowledge this study has certain limitations. Blood pressure measurements were obtained via auscultation and were somewhat difficult to measure in the field under windy conditions. Additionally, for feasibility in collecting data, a number of trained individuals were tasked with obtaining blood pressure. These limitations may explain why we did not observe an expected increase in SBP following the strenuous uphill hike and why reliability measures were not significant for DBP or RPP. Automatic blood pressure sphygmomanometers should be incorporated into future studies to remove the effect of weather condition (i.e., wind) and to eliminate intratester variability effects on the measurements.

In conclusion, the results of this study provide evidence that reliability for select cardiovascular measures can be obtained in a field setting. Additionally, these data show that cardiovascular and perception of exertion measures increase during uphill hiking at a leisure pace. Personal trainers and exercise specialists tend to prescribe exercise programs in the environmentally controlled confines of a fitness facility. Without overstepping the bounds of these findings, it is possible the cardiovascular responses reported here could be used as an initial step in more widespread exercise prescription in an outdoor trail setting. Further investigation is necessary, but it is likely that hiking for a prolonged duration and/or increased frequency could provide sufficient cardiovascular stimulation to induce beneficial physiological adaptations as well as health benefits.

References

- Borg, G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*, 2(2), 92–98.
- Burtscher, M., Bachmann, O., Hatzl, T., Hotter, B., Likar, R., Philadelphia, M., & Nachbauer, W. (2001). Cardiopulmonary and metabolic responses in healthy elderly humans during a 1-week hiking programme at high altitude. *European Journal of Applied Physiology*, 84, 379–386. <http://dx.doi.org/10.1007/s004210100393>

- Cordell, H. K., Green, G. T., Leeworthy, V. R., Stephens, R., Fly, M. J., & Betz, C. J. (2005). *United States of America: Outdoor recreation*. Wallingford, United Kingdom: CABI Publishing.
- Devan, A. E., Lacy, B. K., Cortez-Cooper, M. Y., & Tanaka, H. (2005). Post-exercise palpation of pulse rates: Its applicability to habitual exercisers. *Scandinavian Journal of Medicine and Science in Sports*, 15(3), 177–181. <http://dx.doi.org/10.1111/j.1600-0838.2004.409.x>
- Duckham, R., Bassett, D., Fitzhugh, E., Swibas, T., & McMahan, A. (2009). The effects of hiking poles on performance and physiological variables during mountain climbing. *Journal of Exercise Physiologyonline*, 12(3), 34–41.
- Fletcher, G. F., Balady, G., Blair, S. N., Blumenthal, J., Caspersen, C., Chaitman, B., . . . Pollock, M. L. (1996). Statement on exercise: Benefits and recommendations for physical activity programs for all Americans—A statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association. *Circulation*, 94, 857–862. <http://dx.doi.org/10.1161/01.CIR.94.4.857>
- Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., ... American College of Sports Medicine. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine & Science in Sports & Exercise*, 43, 1334–1359. <http://dx.doi.org/10.1249/MSS.0b013e318213febf>
- Gobel, F. L., Norstrom, L. A., Nelson, R. R., Jorgensen, C. R., & Wang, Y. (1978). The rate-pressure product as an index of myocardial oxygen consumption during exercise in patients with angina pectoris. *Circulation*, 57, 549–556. <http://dx.doi.org/10.1161/01.CIR.57.3.549>
- Jacobson, B. H., Caldwell, B., & Kulling, F. A. (1997). Comparison of hiking stick use on lateral stability while balancing with and without a load. *Perceptual Motor Skills*, 85(1), 347–350. <http://dx.doi.org/10.2466/pms.1997.85.1.347>
- Jacobson, B. H., & Wright, T. (1998). A field test comparison of hiking stick use on heartrate and rating of perceived exertion. *Perceptual Motor Skills*, 87, 435–438. <http://dx.doi.org/10.2466/pms.1998.87.2.435>
- Knight, C. A., & Caldwell, G. E. (2000). Muscular and metabolic costs of uphill backpacking: Are hiking poles beneficial? *Medicine & Science in Sports & Exercise*, 32, 2093–2101. <http://dx.doi.org/10.1097/00005768-200012000-00020>
- Manson, J. E., Hu, F. B., Rich-Edwards, J. W., Colditz, G. A., Stampfer, M. J., Willett, W. C., ... Hennekens, C. H. (1999). A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. *New England Journal of Medicine*, 341, 650–658. <http://dx.doi.org/10.1056/NEJM199908263410904>
- Marniemi, J., Vuori, I., Kinnunen, V., Rahkila, P., Vainikka, M., & Peltonen, P. (1984). Metabolic changes induced by combined prolonged exercise and low-calorie intake in man. *European Journal of Applied Physiology and Occupational Physiology*, 53(2), 121–127. <http://dx.doi.org/10.1007/BF00422574>
- Must, A., Spadano, J., Coakley, E. H., Field, A. E., Colditz, G., & Dietz, W. H. (1999). The disease burden associated with overweight and obesity. *Journal of the American Medical Association*, 282, 1523–1529. <http://dx.doi.org/10.1001/jama.282.16.1523>
- Navalta, J. W., Sedlock, D. A., & Park, K. S. (2004). Physiological responses to downhill walking in older and younger individuals. *Journal of Exercise Physiologyonline*, 7(6), 45–51.
- Office of Disease Prevention and Health Promotion. (2008). Nutrition and weight status - Increase the proportion of adults who are at a healthy weight. Retrieved April 24, 2014, from <http://www.healthypeople.gov/2020/Data/SearchResult.aspx?topicid=29&topic=NutritionandWeightStatus&objective=NWS-8&anchor=140>
- Perrey, S., & Fabre, N. (2008). Exertion during uphill, level, and downhill walking with and without hiking poles. *Journal of Sports Science and Medicine*, 7(1), 32–38.

- Pickering, T. G., Hall, J. E., Appel, L. J., Falkner, B. E., Graves, J., Hill, M. N., . . . Roccella, E. J. (2005). Recommendations for blood pressure measurement in humans and experimental animals: Part 1: Blood pressure measurement in humans: A statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Circulation*, 111, 697–716. <http://dx.doi.org/10.1161/01.CIR.0000154900.76284.F6>
- Porcari, J. P., Hendrickson, T. L., Walter, P. R., Terry, L., & Walsko, G. (1997). The physiological responses to walking with and without Power Poles on treadmill exercise. *Research Quarterly in Exercise and Sport*, 68, 161–166. <http://dx.doi.org/10.1080/02701367.1997.10607992>
- Rodgers, C. D., VanHeest, J. L., & Schachter, C. L. (1995). Energy expenditure during submaximal walking with Exerstriders. *Medicine & Science in Sports & Exercise*, 27, 607–611. <http://dx.doi.org/10.1249/00005768-199504000-00021>