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# The Acute Effects of Therapeutic Activities on Heart Rate and Blood Pressure: A Literature Review

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THE ACUTE EFFECTS OF THERAPEUTIC ACTIVITIES  
ON HEART RATE AND BLOOD PRESSURE:  
A LITERATURE REVIEW.

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MASTER OF SCIENCES THESIS

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**THE ACUTE EFFECTS OF  
THERAPEUTIC ACTIVITIES ON  
HEART RATE AND BLOOD PRESSURE:  
A LITERATURE REVIEW.**

## **ABSTRACT**

This review was initiated to identify the best available evidence on the acute effects of therapeutic activities on heart rate (HR) and blood pressure (BP). The inclusion criteria consisted of studies relevant to the topic that investigated adult subjects. The search covered three major databases using key words related to the topic. Due to the nature of the identified investigations, data were summarized using narrative rather than statistical methodology. A total of 3,447 reports of which 43 met the inclusion criteria were reviewed. There is evidence to suggest that certain therapeutic activities may induce a significant acute increase of HR and BP in adult healthy subjects. Further research is needed to standardize HR and BP measurements and provide a better comparison among the different activities.

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## CHAPTER 1 INTRODUCTION

### Background to the Problem

A study by Frese et al (2002) indicated that practices related to measurement of blood pressure (BP) and heart rate (HR) by physical therapy clinical instructors do not meet the recommendations for physical therapy care<sup>1</sup>, as described in the *Guide to Physical Therapy Practice*.<sup>2</sup> In that research, 52.3% of the 597 respondents stated that HR and BP were not routinely measured because it was not important for their patient population.<sup>1</sup> In a survey with 386 orthopedic physical therapists, Scherer et al (2005) noticed that 75% of the respondents performed some form of cardiovascular screening as part of their examination, but the majority of clinicians reported using subjective patient responses, rather than vital signs, at baseline or during a therapeutic activity.<sup>3</sup>

It has been estimated that 68% of the individuals referred for outpatient orthopedic physical therapy have secondary cardiovascular disease.<sup>4</sup> In the United States alone, high blood pressure currently affects one in four adults and, because there is no symptomatology, nearly one-third of that population is not aware they have this condition.<sup>5</sup>

### Problem Statement

According to the *Guide to Physical Therapy Practice* (2001), a systems review, including HR, BP, and respiratory rate, is part of a comprehensive screening process that is required prior to the initial intervention and it should be performed for all patients/clients.<sup>2</sup> Data from such screening is used by the physical therapists to identify impairments and functional limitations; to establish a diagnosis, prognosis and plan of



care; and to select interventions.<sup>2</sup> Considering greater numbers of patients access physical therapists without a referral<sup>3</sup> and the majority of the physical therapists' procedural interventions involve some type of therapeutic activity, it is important for these health professionals to recognize the acute effects that therapeutic activities have on HR and BP.

### Purpose

Early reports had analyzed the effects of assistive devices and/or therapeutic activities on the cardiovascular system but, perhaps because of the different methodology used in these types of research, no present study exists summarizing these results. Knowledge about the acute effects of HR and BP in relation to therapeutic activities is important in order to provide safer and more accurate treatment prescription, to prevent complications and delayed recovery, and to better comply with the scope of practice according to the *Guide to Physical Therapy Practice* (2001).<sup>2</sup> Thus, the purpose of the present review is to identify and summarize the best available evidence related to the acute effects of therapeutic activities on HR and BP, and to discuss the implications of those findings on clinical decision making.

### Significance of the Problem

Therapeutic activities and exercise, common physiological stress, can elicit abnormal cardiovascular responses that are not present at rest.<sup>6-18</sup> These responses can be influenced by several variables, such as: body position, type of dynamic exercise, certain physical conditions, state of health, blood volume, medications, and environment.<sup>9</sup> In addition, although some exercises may seem to be safe for a certain individual, this cannot be generalized, given that different variables will elicit different responses.

Measurements of HR and BP are vital in helping the health professionals in decision making related to the patient's physiological status and cardiovascular responses to therapeutic activities. Significant cardiovascular changes during exercise have been noticed in studies even with healthy individuals<sup>6-8, 10-15, 17, 18</sup> and such an elevated functional stress on the cardiovascular system could precipitate hazardous events particularly in subjects with unrecognized cardiac diseases.<sup>19</sup>

Therapeutic activities, such as isotonic, isokinetic and isometric exercises, can cause increased stress on the heart of either healthy or sedentary individuals.<sup>18, 20</sup> The immediate response of the cardiovascular system to these exercises is usually an increase in HR due to a decrease in vagal tone.<sup>9</sup> This increase is followed by an increase in sympathetic outflow to the heart and systemic blood vessels. Blood pressure also rises as a result of generalized peripheral vasoconstriction and increased cardiac output (CO).<sup>9</sup> Such cardiovascular changes have been described to precipitate arrhythmias, lipothymic symptoms, acute hypertension and silent myocardial ischemia.<sup>20, 21</sup> Physiological responses to exercise or the ability to exercise can also be affected by systemic medications; a reality for numerous patients who are referred for physical therapy.<sup>22</sup> Therefore, knowledge of cardiovascular changes related to therapeutic activities is recommended in order to set, change and/or discontinue a plan of care.

## **CHAPTER 2**

### **METHODOLOGY**

#### Study Design

A literature review was used to identify and compile the best evidence information related to the acute effects of therapeutic activities on HR and BP. This type of review permits to include studies with different research designs in order to summarize the best available information about the topic.

#### Study Site and Subjects

This review includes studies from peer-reviewed journals that relate to the acute effects of therapeutic activities on HR and BP in the adult population. To be included in the review, the report had to address persons aged 18 years and over, and therapeutic activities related to physical therapy, and measurement of acute HR and/or BP. The exclusion criteria consisted of non-English language reports.

#### Equipment and Instruments

The following electronic search engines were used: Medline (Medical Literature Analysis and Retrieval System Online), ProQuest health and PEDro (Physiotherapy Evidence Database).

#### Validity/Reliability

Only peer-reviewed journals were used in this review.

#### Procedure

An electronic search was conducted using Medline, ProQuest Health and PEDro databases. The following terms were searched and adapted for each database:

blood pressure [and] exercise, heart rate [and] exercise, blood pressure [and] activity, heart rate [and] activity, exercise consequences, blood pressure [and] heart rate, pulse rate [and] exercise, heart rate [and] cycling [or] passive [or] active [or] isometric, cardiovascular [and] responses [and/or] activity.

### Data Analysis

Studies related to the acute cardiovascular effects of activities and exercises associated with physical therapy were selected. Activities were grouped on the following categories: ambulation; strengthening exercises; treadmill and stair climbing. Analysis was based on presenting similarities and discrepancies between the studies, when related to cardiovascular responses, and data was summarized in narrative form, identifying emerging themes, issues of importance, limitations or gaps in the available research.

### Limitations

It may be possible that selection and language bias occurred due to the specificities of the inclusion and exclusion criteria. Summarizing the findings and reaching a conclusion was complicated by the variety of therapeutic activities and patient population, the different protocols to measure HR and BP, and the different study settings utilized.

## CHAPTER 3

### RESULTS

Various combinations of the searched keywords produced different sets of papers, which were screened for relevance by reading titles and abstracts. The search of the literature identified a total of 3,446 articles that referred to cardiovascular responses of therapeutic activities on HR and BP. Of these articles, 80 appeared to meet the inclusion criteria and were selected. Twenty-five articles alluded to a type of activity other than therapeutic. Seven articles provided measurements of cardiovascular effects at least five minutes after the activity and were excluded. Six other articles referred to a different population and also were excluded from this review. Therefore, 42 clinical investigations were included in this review. Papers relevant to the argument but which are not the focus of this review are mentioned in the discussion and full references are given.

#### Ambulation Effects

A significant portion of patients that are referred for physical therapy have usually sustained an injury, surgery or illness and, during the recovery process, many of these may require gait training with or without the aid of an assistive device. Gait training with various assistive devices has been described as vigorous and brief intense exercise<sup>16</sup> and has long been studied in terms of its stress on the heart of an individual performing such a task.<sup>23</sup> Among the devices most commonly selected are the standard walker (SW), wheeled walker (WW) and axillary crutches (AC).<sup>24</sup>

Seven of the studies reviewed in this paper analyzed the acute effects of ambulation, with or without assistive devices, on physiologic responses in subjects without history of cardiovascular disease.<sup>6-8, 10, 14, 19, 24</sup> Six of these indicated the

physiologic responses studied, HR, systolic BP (SBP), diastolic BP (DBP) and/or oxygen consumption (VO<sub>2</sub>), were statistically significant in relation to the type of ambulation studied.<sup>6-8, 10, 14, 19</sup> Dubow et al (1983) reported that during mobility training in elderly subjects with below knee amputations, the energy cost of ambulation is significantly higher than that of wheelchair propulsion.<sup>10</sup> It is suggested that precautions should be taken when prescribing assistive devices, specially for older patients and patients with deconditioning or cardiovascular and/or pulmonary disease.<sup>6-8, 10, 19</sup> According to these studies, the need for precautions when prescribing assistive devices is based on the fact that

- myocardial V<sub>O2</sub>, mean HR, and BP values during nonweight-bearing (NWB) with AC were significantly higher than resting levels
- HR values during NWB use of SW were considerably elevated, when compared to baseline values
- tendency of HR, ventilation volume, and rate of perceived exertion (RPE) to continuously rise during AC walking, and
- overall energy costs and HR demands during use of AC were also significantly higher than baseline.

Only one study found no significant changes in physiologic responses during ambulation with assistive devices.<sup>6</sup>

### Effects of Strengthening Exercises

Different types of strengthening exercise can be used as a mechanism for gradually increasing the energy demand placed on a patient during a cardiac

rehabilitation program.<sup>25</sup> The level of demand imposed by the exercise can be directly influenced by numerous variables, such as type of activity, patient's level of conditioning and patient's medical history/status. The clinician should be aware of the cardiovascular effects of strengthening exercises on the patient in order to obtain accurate knowledge of the energy costs involved and, consequently, administer an appropriate exercise regimen.

According to the *Guide to Physical Therapy Practice* (2001), therapeutic exercise is part of the core of most physical therapy plans of care<sup>2</sup> and physical therapists, as experts in developing, implementing and evaluating therapeutic exercise programs, are expected to be aware of typical responses to the various types of exercise prescribed. However, little attention is given to the physiologic responses of the cardiovascular system to exercises in individuals whose primary problem is orthopedic.<sup>26</sup>

Isokinetic dynamometers are devices which resist applied forces and control the speed of exercise at a predetermined rate. This type of apparatus is designed for the measurement of maximum voluntary muscle activity and is commonly used in performance assessment, development of strength and endurance for everyday activities, and for specific recreational and elite athletic pursuits. Previous studies have used a dynamometer to conduct orthopedic isokinetic resistance exercises in healthy subjects, which revealed a significant increase in HR, SBP, rate pressure product (RPP) and V<sub>O2</sub> as acute responses.<sup>11-13, 18, 20-22, 25, 27</sup> Half of the studies on isokinetic exercise, incorporated in this report, noted the highest mean SBP, and large increases in HR and/or CO values which were similar to those occurring during maximal cycling or treadmill exercise.<sup>12, 13, 22, 25,</sup> Haennel et al (1992) and McMeeken et al (1995) noticed that in healthy young or middle-age subjects, there is a gradual increase in BP during dynamic

exercises, such as treadmill or bicycle testing, compared to a significant rapid increase in BP that occurred within the first minute of initiating an isokinetic test.<sup>12, 13</sup> However, the authors agree these types of exercise have the capacity to make similar demands on the cardiovascular system in healthy subjects.

During maximal isokinetic exercise, it has been observed that the magnitude of the cardiovascular responses is dependent of the exercise intensity and the size of the active muscle mass, rather than the velocity of the movement.<sup>12, 17</sup> However, significant stress on the cardiovascular system has also been noticed during submaximal protocols of concentric and eccentric isokinetic exercises; with the former presenting a more pronounced response.<sup>18, 20</sup> It is suggested that due to the increased cardiovascular demand of these exercises, individuals performing this type of activity should be screened prior to initiating such activities and, due to a potential decrease in the SBP and HR, sometimes undershooting resting levels, monitoring may also be warranted during repetitions and rest intervals.<sup>11, 13, 18, 20, 28, 30, 41, 43</sup>

Al-Obaidi et al (2001) published what may be the only study on the cardiovascular effects of repetitive McKenzie exercises.<sup>28</sup> Following a protocol commonly used in orthopedic assessment and management of back pathology, the authors analyzed the effects of lumbar spinal flexion and extension in standing and lying. According to the authors, an increased RPP is an indicator of increased myocardial oxygen demand, which suggests that these McKenzie exercises represent a risk for a patient with underlying cardiovascular dysfunction.<sup>28</sup> In another study using isotonic exercises in healthy subjects, the use of 50% of one repetition maximum (RM) revealed a statistically significant increase in HR while 80% 1RM showed an increase in both HR



and SBP.<sup>29</sup> Rezk et al (2006) also noticed an increase in HR after 40 and 80 % 1 RM in healthy subjects however a decrease in SBP was observed during the same interventions.<sup>30</sup>

Isotonic exercises of low or high intensities can cause adverse cardiovascular responses, including systolic post-exercise hypotension, which is due to a decrease in CO that is not compensated by an increase in systemic vascular resistance.<sup>30</sup> Upper and lower extremities isotonic exercises based on a typical cardiac rehabilitation program also have shown to significantly increase HR and V02 in healthy subjects, especially when executed in a semi-Fowler position.<sup>25</sup> Although this gradual increase in activity level might be the goal in early acute recovery of a patient post-cardiac surgery, these effects should be taken into consideration when dealing with a patient post-orthopedic surgery with known or unknown cardiovascular problems.

Continuous isometric muscle contraction is considered one of the most useful exercises to improve muscle strength.<sup>31</sup> In isometric exercise, the rate of rise in BP is proportional to the relative intensity of contraction as expressed by the percentage of the maximum voluntary contraction force (MVC) and the duration of the contraction. Several investigations in this review analyzed the effects of different parameters of MVC on upper or lower extremity flexors.<sup>15, 20, 21, 32-36</sup> Using two or three-minute contractions and MVC between 30 and 40%, five studies noticed an increase in acute HR and BP during isometric handgrip.<sup>32, 34-37</sup> Altogether the subjects in those studies consisted of healthy adults, healthy older adults and patients with either Type 2 diabetes, paraplegia or peripheral atherosclerotic disease. Five reports also observed a significant increase in HR and BP during knee extension with MVC varying between 30 and 100%.<sup>20, 21, 33, 35, 36</sup> In a

study with isometric activity, Cassady et al (2001) observed that three minutes of continuous abdominal stabilization exercise performed on a therapeutic exercise ball elicited a significant increase in HR.<sup>15</sup> The relative exercise intensities ranged from 36 to 88% of age-predicted maximal heart rates (APMHR), exceeding the range of 40 to 50% of APMHR, the typically prescribed exercise intensities for deconditioned individuals.<sup>15</sup> Findings of these studies suggest the need for a cardiovascular examination before subjects undergo isometric exercise protocols of even submaximal intensity.<sup>15, 20, 21, 31, 33, 35, 36</sup> The potential detrimental effects of prescribing strengthening activities without proper assessment and monitoring can be worsened in patients with unrecognized cardiovascular disease.

#### Treadmill and Stair Climbing Effects

When using treadmill, either for testing or as a therapeutic activity, the clinician should be alert to the possibility of adverse responses during and after the procedure. Factors such as intensity of exercise and rate of perceived exertion should be taken into consideration whenever exercise testing or training is required in individuals with or without heart disease.<sup>38</sup> An exaggerated BP response pattern to treadmill exercise could represent impairment in cardiovascular adjustment to exercise<sup>39</sup> and it has been identified as a predictor of either exercise-induced or new-onset hypertension in normotensive men and women.<sup>40</sup>

Several studies have found abnormal HR and BP recovery during treadmill testing in subjects with or without known cardiovascular diseases.<sup>40-42</sup> Early or delayed change in BP during treadmill exercise has been observed as a warning of the risk of hypotension symptoms.<sup>43, 44</sup> Although a late hypotensive response, when characterized by a decline in

BP after five minutes of continuous exercise, was found to be six times more frequent than early hypotensive response in subjects with or without history of cardiac disease.<sup>44</sup>

During treadmill gait training with the use of neuromuscular electrical stimulation (NMES), changes in BP have also been noticed in subjects with quadriplegia without history of cardiovascular disease.<sup>43</sup> Carvalho et al (2005) noticed that in patients with quadriplegia, BP and HR would significantly increase during gait training, with NMES, and a decrease in BP would occur during the recovery phase.<sup>43</sup> Considering the increase in survival rates of individuals with high level spinal cord injury<sup>45</sup> and the growing likelihood that clinicians will manage patients with cardiovascular disease in direct access, physical therapists should become accustomed to generally and routinely monitoring patients' cardiovascular responses to exercise as a testing or therapeutic tool. Although submaximal treadmill testing is not a common routine exam throughout all physical therapy patient populations, the use of treadmill as a therapeutic activity is a common practice with different patient populations, and results similar to that of treadmill testing can be reached depending on the rehabilitation protocol used.

Stair climbing has been shown to markedly rise HR and VO<sub>2</sub> during the first 60 seconds of climbing<sup>46</sup>, and to elicit higher HR response than weight lifting.<sup>47</sup> One clinical trial evaluated the BP, HR and VO<sub>2</sub> of 103 subjects during stair climbing and found that ascending stairs in a brisk, constant pace may elicit increased SBP, HR and VO<sub>2</sub> values that are well above the recommended minimum intensity for attaining cardiorespiratory benefits.<sup>47</sup> When compared to weight lifting, cycle exercise, horizontal and uphill walking, stair climbing at least at a moderate pace was found to elicit the highest cardiopulmonary stress among all five types of exercise.<sup>47, 48</sup> These results suggested that

climbing only three to four flights of stairs even at a moderate pace may elicit peak circulatory demands similar to 10 minutes of horizontal walking at 2.5 mph intermittently carrying a 30-pound weight or four minutes of walking up a moderately steep slope.<sup>47</sup>

Stair climbing as part of a rehabilitation program is most commonly incorporated in the treatment of orthopedic conditions usually focusing on functional mobility rather than on cardiovascular training. Further research is necessary to identify if stair climbing at intensities normally used during rehabilitation programs would elicit responses similar to those of previous investigations. Given the uncertainty of acute effects stair climbing may evoke, either as a therapeutic or a testing tool, in a patient with or without known heart disease, it is important that clinicians monitor the patients' BP and HR when appropriately necessary; such as during an examination.

**CHAPTER 4**  
**DISCUSSION AND IMPLICATIONS**  
Application to Practice

Despite the considerable amount of research addressing the acute cardiovascular effects of different types of activities, there has been little attempt to address these effects related to therapeutic activities in the presence of pathologies, and it might be difficult to predict patient responses based on investigations that use healthy subjects as their study population. Although the subjects used in these studies had physiologic responses within an acceptable range to perform these activities, normal baseline cardiovascular values do not necessarily indicate that patients will demonstrate satisfactory cardiovascular responses to therapeutic activities. Furthermore, a low intensity activity, such as walking, may be considered vigorous exercise depending on the patient's conditioning level.<sup>3</sup> Clinicians should also consider the possibility of an unknown pathology, cardiovascular or not, which could compromise the effects of these activities on the patient's cardiorespiratory system.

The greater majority of the papers studied in this review found significant increase in the work of the heart as an acute response from the therapeutic activity used. Of particular importance for having HR and BP monitored are the geriatric or the deconditioned population, and those with cardiorespiratory or cardiac problems.<sup>6-8, 19</sup> Activities likely to induce an acute increase in the physiologic responses may also occur outside the clinical facility, such as in a fitness center or in a home setting. In that case appropriate precautions should be taken to perform previous exercise testing and/or

provide cardiovascular monitoring, such as telemetry monitoring if appropriate, or patient/caregiver education about measurement of HR and BP.

Submaximal exercise testing is recommended when prescribing low or moderate intensity exercises<sup>3</sup> and patients with cardiac and/or pulmonary risk should have HR and BP monitored when performing prescribed therapeutic activities.<sup>28</sup> Knowledge of the patient's cardiovascular condition might result in a change of patient management and a reduction in the number of unforeseen outcomes. On this basis, HR and BP measurements should be readily incorporated as part of the patient's assessment and, whenever appropriate, during the course of the treatment.

#### Research Suggestions

Suggestions for future investigations include studying the role of cardiovascular effects of therapeutic activities on patients in the presence of pathologies, especially pathologies commonly treated by the physical therapist, as well as the effects of such activities in specific conditions, such as pediatric and adult obesity. It's also important for a clinician to be able to compare the cardiovascular effects of activities that were not included in this paper but are commonly used as part of a plan of care; such as hydrotherapy. Another research topic would be establishing the optimal approach to measure HR and BP during these activities, considering it is more accurate to compare HR and BP values that are measured using the same method. Additional areas to investigate include: verifying clinician's awareness regarding monitoring of physiologic responses, and determining changes in the practice of cardiovascular monitoring during therapeutic activities, i.e. are clinicians actually performing these assessments, and how often and under what circumstances are they performing them.

Investigation on these topics would certainly provide additional evidence to support recommendations that measurement of physiologic responses should be incorporated into routine care. It could also contribute to better medical care of the patient by providing the clinician with a better understanding about the physiologic responses of different therapeutic activities; prevention/monitoring of cardiovascular diseases; and more appropriate treatment prescription.

### Summary

This review shows the available research related to the acute effects of therapeutic activities on HR and BP, and it highlights the lack of investigation on topics more specific to physical therapy. According to the above review, significant increases in HR and BP values can be seen in a great variety of therapeutic activities. When considering the potential detriments these activities may have, even on healthy subjects, it becomes best practice to incorporate appropriate precautions on patient management. In order to prevent unexpected cardiovascular responses and provide appropriate treatment, the clinician should be aware of the patient's baseline cardiovascular values, especially when dealing with the geriatric or deconditioned population, and patients with cardiac or cardiorespiratory problems.

Physical therapists have a responsibility to recognize and prevent intolerance to exercise, thereby minimizing the risks of physical activity guiding each patient in selecting a safe, yet beneficial, level of activity during treatment.<sup>8</sup> Current evidence suggests that the majority of physical therapy clinical instructors do not measure their patients' HR and BP, and most of these are based on the rationale that "it is not important for my patient population".<sup>1</sup> Additional research is needed in order to provide greater

understanding about the importance of this topic, and to ensure appropriate patient management.



## REFERENCES

- 1) Frese, E. M., Ritcher, R. R. & Burlis, T.V. (2002). Self-reported measurement of heart and blood pressure in patients by physical therapy instructors. *Physical Therapy*, 82(12), 1192-1200.
- 2) American Physical Therapy Association. (2001). *Guide to Physical Therapy Practice*. Alexandria, VA: American Physical Therapy Association.
- 3) Scherer, S.A., Noteboom, J.T., Flynn, T.W. (2005). Cardiovascular assessment in the orthopaedic practice setting. *Journal of Orthopaedics and Sports Physical Therapy*, 35, 730-737.
- 4) Billek-Sawhney, B. (1998). Cardiovascular considerations in outpatient orthopedic physical therapy [abstract]. *Journal of Orthopaedic and Sports Physical Therapy*, 27(1), 57.
- 5) American Heart Association. (n.d.). *High Blood Pressure*. Retrieved November 1, 2003 from <http://www.amhrt.org/presenter.jhtml?identifier=2114>
- 6) Bhambani, Y. & Clarkson, H. (1989). Acute physiologic and perceptual responses during three modes of ambulation: walking, axillary crutch walking, and running. *Archives of Physical Medicine and Rehabilitation*, 70, 445-450.
- 7) Kathrins, B. P. & O'Sullivan, S. D. (1984). Cardiovascular responses during nonweight-bearing and touchdown ambulation. *Physical Therapy*, 64(1), 14-18.
- 8) Baruch, I.M. & Mossberg, K.A. (1983). Heart-rate response of elderly women to nonweight-bearing ambulation with a walker. *Physical Therapy*, 63(11), 1782-1787.
- 9) Fletcher G.F., Balady G.J., Amsterdam E.A., Chaitman, B., Eckel, R., Fleg, J., et al. (2001). Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation*, 104, 1694-1740.
- 10) DuBow, L.L., Witt, P.L., Kadaba, M.P., Reyes, R., Cochran, G.V.B. (1983). Oxygen Consumption of elderly persons with bilateral below knee amputations: ambulation vs wheelchair propulsion. *Archives of Physical Medicine and Rehabilitation*, 64, 255-259.

- 11) Solomon K. (1992). Blood Pressure and heart rate responses to a standard lower limb isokinetic test. *Australian Journal of Physiotherapy*, 38, 95-102.
- 12) Haennel R.G., Snydermilller, G. D., Teo, K. K., Greenwood, P. V., Quinney, H. A., Kappagoda, T. (1992). Changes in blood pressure and cardiac output during maximal isokinetic exercise. *Archives of Physical Medicine and Rehabilitation*, 73,150-155.
- 13) McMeeken, J. M., Nall, C. M., McNicol, P. L., Globe, A., Fleming, J. (1995). Investigation of the effects of isokinetic knee assessment on cardiovascular parameters in middle-aged subjects. *Physiotherapy Theory and Practice*, 11, 157-164.
- 14) Waters, R. L., Campbell, J., Perry, J. (1987). Energy cost of three-point crutch ambulation in fracture patients [abstract]. *Journal of Orthopedic Trauma*, 11, 170-173.
- 15) Cassady, S. L., Levsen, M., DeBrower, A., (2001). Cardiorespiratory responses to abdominal stabilization exercises performed on a therapeutic exercise ball. *Cardiopulmonary Physical Therapy*, 12, 83-87.
- 16) Amundsen, L.R. (1979). Assessing exercise tolerance: a review. *Physical therapy*, 59(5), 534-537.
- 17) Lewis, S. F., Snell, P. G., Taylor, W. F., Hamra, M., Graham, R. M., Pettinger, W. A. et al. (1985). Role of muscle mass and mode of contraction in circulatory responses to exercise. *Journal of Applied Physiology*, 58(1), 146-151.
- 18) Thompson, E., Versteegh, T. H., Overend, T. J., Birmingham, T.B., Vandervoort, A. A. (1999). Cardiovascular responses to submaximal concentric and eccentric isokinetic exercise in older adults. *Journal of Aging and Physical Activity*, 7, 20-31.
- 19) Hinton, C. A. & Cullen, K. E. (1982). Energy expenditure during ambulation with ortho crutches and axillary crutches. *Physical Therapy*, 62(6), 813-819.
- 20) Iellamo, F., Legramante, J.M., Raimondi, G., Castrucci, F., Damiani, C., Foti, C., et al. (1997). Effects of isokinetic, isotonic and isometric submaximal exercise on heart rate and blood pressure. *European Journal of Applied Physiology and Occupational Physiology*, 75(2), 89-96.

- 21) Huggett, D.L., Elliott, I.D., Overend, T.J., Vandervoot, A.A. (2004). Comparison of heart-rate and blood-pressure increases during isokinetic eccentric versus isometric exercise in older adults. *Journal of Aging and Physical Activity*, 12(2), 157-169.
- 22) Alland, M. J. & Peel, C. (1990). Cardiovascular responses to isokinetic trunk exercise. *Physical Therapy*, 70(8), 503-509.
- 23) Fisher, S.V. & Gullickson, G.Jr. (1978). Energy cost of ambulation in health and disability: a literature review. *Archives of Physical Medicine and Rehabilitation*, 59(3), 124-133.
- 24) Holder, C. G., Haskvitz, E. M., & Weltman, A. (1993). The effects of assistive devices on the oxygen cost, cardiovascular stress, and perception of nonweight-bearing ambulation. *Journal of Orthopaedics and Sports Physical Therapy*, 18(4), 537-542.
- 25) Dehne, P. R. & Protas, E. J. (1986): Oxygen consumption and Heart rate responses during five active exercises. *Physical Therapy*, 66(8), 1215-1219.
- 26) Negus, R. A., Rippe, J. M., Freedson, P. & Michaels, J. (1987). Heart rate, blood pressure, and oxygen consumption during orthopaedic rehabilitation exercise. *Journal of Orthopaedic and Sports Physical Therapy*, 8(7), 346-350.
- 27) Douris, P.C. (1991). Cardiovascular responses to velocity-specific isokinetic exercise. *Journal of Orthopaedics and Sports Physical Therapy*, 13(1), 28-32.
- 28) Al-Obaidi, S., Al-Shuwai, N., Anthony, J. & Dean, E. (2001). Cardiovascular responses to repetitive McKenzie lumbar spine exercises. *Physical Therapy*, 81(9), 1524-1533.
- 29) Focht, B. & Koltyn, F.K. (1999). Influence of resistance exercise of different intensities on state anxiety and blood pressure. *Medicine & Science in Sports and Exercise*, 31(3), 456-463.
- 30) Rezk, C.C., Marrache, R.C., Tinucci, T., Mion, D., Forjaz, C.L. (2006). Post-resistance exercise hypotension, hemodynamics, and heart rate variability: influence of exercise intensity. *European Journal of Applied Physiology*, 98(1), 105-112.

- 31) Yamamoto, M., Tajima, F., Okawa, H., Mizushima, T., Umezu, Y. & Ogata, H. (1999). Static exercise-induced increase in blood pressure in individuals with cervical spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, 80, 288-293.
- 32) Goldberg, L.I., White, D.J. & Pandolf, K.B. (1982). Cardiovascular and perceptual responses to isometric exercise. *Archives of Physical Medicine and Rehabilitation*, 63(5), 211-216.
- 33) O'Connor, P., Sforzo, G.A. & Frye, P. (1989). Effect of breathing instruction on blood pressure during isometric exercise. *Physical Therapy*, 69(9), 757-765.
- 34) Bakke, E.F., Hisdal, J., Kroese, A.J., Jorgensen, J.J., Strandén, E. (2007). Blood pressure response to isometric exercise in patients with peripheral atherosclerotic disease. *Clinical Physiology and Functional Imaging*, 27(2), 109-115.
- 35) Petrofsk J.S. (2001). Blood pressure and heart rate response to isometric exercise: the effect of spinal cord injury in humans. *European Journal of Applied Physiology*, 85(6), 521-526.
- 36) Ray, C., Wilson, T. (2004). Comparison of skin sympathetic nerve responses to isometric arm and leg exercise. *Journal of Applied Physiology*, 97(1), 160-164.
- 37) Petrofsk, J.S., Stewart, B., Patterson, C., Cole, M., Maly, A.A., Lee, S. (2005). Cardiovascular responses and endurance during isometric exercise in patients with type 2 diabetes compared to control subjects. *Medical Science Monitor*, 11(10), 470-477.
- 38) Balogun, M.O., Sulyman, B.O., Akinwusi, P.O. (1997). A comparison of the cardiovascular responses to treadmill and bicycle ergometer exercise in healthy male nigerians. *African Journal of Medicine and Medical Sciences*, 26(1-2), 27-30.
- 39) Diwan, S.K., Jaiswal, N., Wanjari, A.K., Mahajan, S.N. (2005). Blood pressure response to treadmill testing among medical graduates: the right time to intervene. *Indian Heart Journal*, 57(3), 237-240.
- 40) Singh, J.P., Larson, M.G., Manolio, T.A., O'Donnell, C.J., Laue, r M., Evans, J.C., et al. (1999). Blood pressure response during treadmill testing as a risk factor for new-onset hypertension: the Framingham heart study. *Circulation*, 99, 1831-1836.

- 41) McHam, S.A., Marwick, T.H., Pashkow, F.J., Lauer, M.S. (1999). Delayed systolic blood pressure recovery after graded exercise: an independent correlate of angiographic coronary disease. *Journal of the American College of Cardiology*, 34(3), 754-759.
- 42) Messinger-Rapport, B., Snaider, C.E.S., Blakstone, E.H., Yu, D., Lauer, M.S. (2003). Value of exercise capacity and heart rate recovery in older people. *Journal of the American Geriatrics Society*, 44(2), 121-125.
- 43) Carvalho, D.C., Cliquet, A. Jr. (2005). Response of the arterial blood pressure of quadriplegic patients to treadmill gait training. *Brazilian Journal of Medical and Biological Research*, 38(9), 1367-1373.
- 44) Watson, G., Mechling, E., Ewy G.A. (1992). Clinical significance of early vs. late hypotensive blood pressure response to treadmill exercise. *Archives of Internal Medicine*, 152(5), 1005-1008.
- 45) Orest, M.R., Shearer, C.F. (2001). Acute care physical therapy management of a patient with a C2 fracture resulting in tetraplegia. *Neurology Report*, 25, 12-19.
- 46) Teh, K.C., Aziz, A.R. (2002). Heart rate, oxygen uptake, and energy cost of ascending and descending the stairs. *Medicine and Science in Sports and Exercise*, 34(4), 695-699.
- 47) Benn, S.J., McCartney, N., McKelvie, R.S. (1996). Circulatory responses to weight lifting, walking, and stair climbing in older males. *Journal of the American Geriatrics Society*, 44(2), 121-125.
- 48) Brunelli, A., Refai, M.A., Monteverde, M., Borri, A., Salati, M., Fianchini, A. (2002). Stair climbing test predicts cardiopulmonary complications after lung resection. *Chest*, 121, 1106-1110.