

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

THE ACCURACY OF HEART RATE-BASED ZONE TRAINING USING
PREDICTED VERSUS MEASURED MAXIMAL HEART RATE

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Science

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Clinical Exercise Physiology

December, 2017

THE ACCURACY OF HEART RATE-BASED ZONE TRAINING USING
PREDICTED VERSUS MEASURED MAXIMAL HEART RATE

By Amanda Leonard

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

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ABSTRACT

Leonard, A. The accuracy of heart rate-based zone training using predicted versus measured maximal heart rate. MS in Clinical Exercise Physiology, December 2017, 50pp. (J. Porcari)

Predicted maximal heart rate (PMHR) equations are used in a variety of settings for exercise prescription. However, their efficacy is often questioned in the literature. The purpose of this study was to examine the accuracy of heart rate-based zone training using PMHR versus measured maximal heart rates (MMHR). Twenty-six college-aged subjects participated in the current study. Subjects reported to the laboratory for two separate testing sessions; a PMHR-based zone training session and a maximal treadmill test to determine MMHR. No significant difference was found between MMHR and PMHR and the correlation between the two values was $r=0.45$. Eighty-two percent (150/182) of the time subjects were in the correct PMHR zone based on their MMHR. When subjects were not in the correct zone, their heart rates (HR) were not off by a large range (1-8 bpm) and were only off by one zone. In conclusion, the current study suggests that for college-aged students, using PMHR to define training zones is fairly accurate; the majority of the time subjects will be in the correct HR zone. However, for those who cannot attain specific zones, we advise the usage of an RPE scale in conjunction with an age PMHR equation.

ACKNOWLEDGEMENTS

I would first like to thank all of the subjects who volunteered their time to participate in my study. Thank you for working with me to schedule your lab sessions and allowing me to practice my laboratory skills on you. Thank you to those who helped me conduct the research and being a second hand – it really helped move testing along quickly and smoothly. Next I would like to thank Chris Dodge for always helping me out in the lab and making me smile when days got long. You really brightened my experience in the lab. I would also like to thank my committee members, Scott Doberstein and Susan Bramwell. Thank you for taking the time out of your schedules to meet with me and provide me with additional help. Finally, a big thank you is in order to Dr. John Porcari. Thank you for your patience and for providing me with your knowledge on so many different aspects of this entire thesis process. I literally could not have done this without you – and your food to fuel my brain! It has been a long process over the past year and I am forever grateful for your guidance.

TABLE OF CONTENTS

	PAGE
ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	iv
LIST OF TABLES.....	vi
LIST OF APPENDICES.....	vii
INTRODUCTION.....	1
MATERIALS & METHODS.....	4
Subjects.....	4
Experimental Design.....	4
STATISTICAL ANALYSIS.....	6
RESULTS.....	7
Figure 1. Relationship between PMHR (bpm) and MMHR (bpm).....	8
DISCUSSION.....	9
REFERENCES.....	12
APPENDICES.....	13

LIST OF TABLES

TABLE	PAGE
1. Training intensity zones (ACSM)	1
2. Intensity zones using % HRmax as defined by Edwards (1992)	2
3. Descriptive characteristics of subjects	7
4. Descriptive characteristics of average RPE, % MMHR, and % PMHR.....	7

LIST OF APPENDICES

APPENDIX	PAGE
A. Informed Consent	13
B. PAR-Q & YOU	18
C. Risk Factor Assessment Form.....	20
D. Data Collection Sheets	23
E. Rating of Perceived Exertion Scale.....	26
F. Review of Literature.....	28

INTRODUCTION

Measuring heart rate (HR) has been used for many years to evaluate how hard the heart is working before, during, and after exercise (Karvonen, Kentala, & Mustala, 1957). Heart rate is also widely used in a variety of settings for exercise prescription. Individuals are often given a target HR range based on a percentage of their heart rate maximum (HRmax) or heart rate reserve (HRR) (Karvonen, Kentala, & Mustala, 1957).

Target HRs are calculated to get individuals into different “training zones.” The American College of Sports Medicine (ACSM) defines zones for the general population (Table 1) using either a percentage of HRmax or as a percentage of HRR (ACSM, 2014).

Table 1. Training intensity zones (ACSM).

Intensity Zone	% HRmax	% HRR
Light	57-63%	30-39%
Moderate	64-75%	40-59%
Vigorous	76-95%	60-89%
Maximal	96-100%	90-100%

However, for athletes, defining zones is often done in stages as first described by (Edwards, 1992), who defines five training zones based upon five different levels of intensity (Table 2).

Table 2. Intensity zones using % HRmax as defined by Edwards (1992).

Intensity Zone	% HRmax
Moderate activity	50-60%
Weight management	60-70%
Aerobic	70-80%
Anaerobic threshold	80-90%
Red-Line	90-100%

Zone training is one of the latest trends in exercise prescription and is gaining popularity. One fitness approach that utilizes zone training is Orangetheory Fitness (<http://www.orangetheoryfitness.com>). Maximal HR is predicted for new members based upon an assessment of physical activity level, age, gender, height, and weight. Five HR zones are then calculated based on this predicted maximal heart rate (PMHR). A HR monitor is worn by each member so it can be continuously monitored throughout an instructor-led 60-minute workout. Heart rates are projected on a screen so members can see whether or not their HRs are falling within a given zone. The goal of Orangetheory Fitness is to have members working in zones 4/5, or at 84% PMHR or higher, for 12-20 minutes. The theory behind this is what Orangetheory Fitness refers to as excess post-exercise oxygen consumption (EPOC), which is supposedly elevated after high-intensity training. The Orangetheory website (<http://www.orangetheoryfitness.com>) states that metabolic rate will be increased for up to 36 hours post workout if members train in zones 4/5 for 12-20 minutes.

The best way to determine HRmax is with a graded maximal exercise test (GXT). However, many times it is not feasible to perform a GXT to determine HRmax and maximal testing can present risks among elderly, sick, or sedentary individuals. Therefore, equations have been derived to predict HRmax, most of which are based on

age. The most commonly used equation to predict HRmax is $PMHR=220-age$ (Robergs & Landwehr, 2002). Although PMHR is a good estimate and an alternative to measuring HRmax in most individuals, the standard deviation of PMHR using this equation is $\pm 10-12$ bpm (ACSM, 2014).

This large variation in PMHR has led to the development of alternate equations. A commonly used method was developed by Gellish and colleagues (2007). They used a number of variables to try and predict HRmax including age, gender, body mass index (BMI), and resting HR. The resulting equation was $PMHR=207-0.7(age)$. The major advantage of this equation is that the standard deviation is only $\pm 5-8$ bpm, whereas the standard deviation of the equation developed Fox et al. (1971) is $\pm 10-12$ bpm.

The purpose of this study was to determine the accuracy of HR-based zone training using PMHR versus measured maximal heart rate (MMHR). We hypothesized that there would be significant differences in the ability of individual subjects to attain target HR zones based upon PMHR versus MMHR.

MATERIALS AND METHODS

Subjects

Subjects were recruited from the University of Wisconsin-La Crosse and surrounding community. Inclusion criteria for this study required being apparently healthy and physically active. Each subject was provided with an informed consent document (Appendix A) by the investigators. The study protocol was explained to each subject prior to signing the informed consent form. Subjects then completed a PAR-Q (Appendix B) and risk factor assessment form (Appendix C) to screen for orthopedic and cardiovascular contraindications to exercise. Approval of the study was given by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects.

Experimental Design

Each subject attended two testing sessions on separate days. During the first session, subjects completed the health and exercise history questionnaires and written informed consent was obtained. Subject's PMHR was then estimated using the equation of Gellish et al. (2007). A 35-minute exercise bout on a treadmill using HR-based zones based on the subject's PMHR was then completed. The treadmill test was divided into seven, 5-minute training zones based on the subject's PMHR. The five intensity zones that were used in this study were: Zone 1 = 50-59% PMHR; Zone 2 = 60-69% PMHR; Zone 3 = 70-79% PMHR; Zone 4 = 80-89% PMHR; and Zone 5 = 90-100% PMHR. The order of the seven, 5-minute zones were as follows: 1, 3, 2, 4, 2, 5, and 2. Pilot data

indicated that Zone 1 could not reasonably be achieved after the warm-up period, thus zone 1 was not included in the later stages. Heart rate was recorded during the exercise session using radiotelemetry (Polar Electro Oy, Port Washington, NY) at 4:30 and 5:00 minutes during each 5-minute segments. The two HRs were then averaged to get an overall HR for all seven segments. Ratings of perceived exertion (RPE) were assessed at the end of each 5-minute segment using the Borg 6-20 scale (Borg, 1973).

Each subject then returned to the laboratory, with a minimum of 48 hours separating the sessions, and performed a maximal incremental treadmill test to determine HR_{max} and VO₂_{max}. The test started at a self-selected walking or running speed and a grade of 0%. The grade was increased by 2.5% every 2 minutes until the subject reached volitional exhaustion. During the test, HR was measured once again using radiotelemetry, identical to session one, and expired air was measured using an AEI metabolic cart (AEI, Pittsburgh, PA). Prior to the test, calibration of the metabolic cart was conducted using reference gases (oxygen and carbon dioxide) and the pneumotach was calibrated with a 3-liter syringe. Maximal oxygen consumption was defined as the highest continuous 30 seconds of VO₂ reading during the test.

STATISTICAL ANALYSIS

Standard descriptive statistics were used to assess baseline physical characteristics of the subjects and averages of RPE, % MMHR, and % PMHR. Comparisons between the numbers of times the subjects were in the correct zone based on PMHR versus MMHR were made by calculating the number of times subjects measured HR didn't land in their PMHR zones. Pearson product-moment correlation was used to assess the correlation between PMHR and MMHR. An alpha level of $p < 0.05$ was considered to be statistically significant. Data were analyzed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL).

RESULTS

Initially, there were 28 subjects in the study. One subject did not achieve a respiratory exchange ratio value over 1.0, and one subjects' data was removed due to technical difficulties when the HR monitor did not capture HR during the last stage of the VO₂max test. Descriptive characteristics of the 26 subjects who completed the study are presented in Table 3.

Table 3. Descriptive characteristics of subjects (N=26).

	Female (n=13)	Male (n=13)
Age (yrs.)	21.2 ± 2.42	20.3 ± 1.11
Height (in)	63.7 ± 1.64	71.2 ± 2.82
Weight (lbs)	136.0 ± 11.79	186.0 ± 18.79
VO ₂ max (mL/kg/min)	50.9 ± 5.00	58.4 ± 5.53

Data are reported as mean ± standard deviation.

Descriptive characteristics were also used to find averages of RPE, % MMHR, and % PMHR for all seven segments of the 35-minute treadmill protocol as seen in Table 4.

Table 4. Descriptive characteristics of average RPE, % MMHR and % PMHR.

Zone	Average RPE	Average % MMHR	Average %PMHR
1	7.6 ± 1.13	55.3 ± 2.51	55.1 ± 2.36
3	10.8 ± 1.81	76.5 ± 3.80	76.2 ± 2.89
2	9.4 ± 1.71	64.6 ± 3.06	64.3 ± 1.98
4	13.0 ± 2.28	87.0 ± 3.44	86.7 ± 1.90
2	9.5 ± 1.63	64.5 ± 3.51	64.3 ± 2.73
5	16.0 ± 2.78	96.3 ± 2.72	96.0 ± 1.79
2	8.7 ± 1.58	66.7 ± 3.45	64.4 ± 2.82

Data are reported as mean ± standard deviation.

Overall average MMHR was 192 ± 6.6 bpm and the overall average PMHR was found to be 193 ± 1.3 bpm. There was no significant difference between MMHR and PMHR and the correlation between the two values was $r=0.45$. It was found that 14 subjects (54%) had a MMHR greater than their PMHR and 12 subjects (46%) had a MMHR less than their PMHR. A graph of MMHR vs. PMHR is presented in Figure 1.

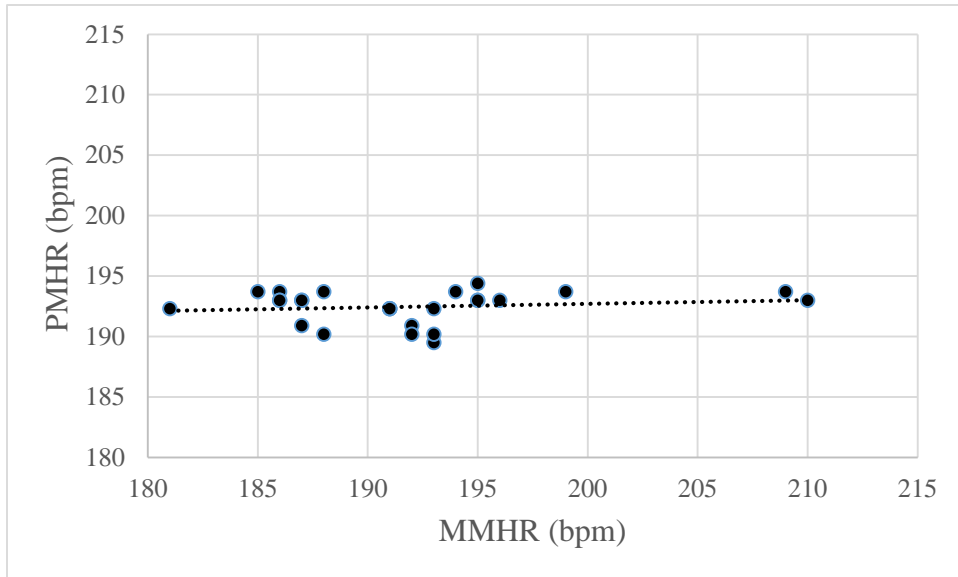


Figure 1. Relationship between PMHR and MMHR.

Training zones were calculated based upon PMHR. Eighty-two percent (150/182) of the time subjects actual HRs were in the correct zone based on their PMHR, whereas 18% (32/182) of the time subjects measured HR did not fall within the correct PMHR zone. When measured exercise heart rates were above the targeted zone, HR was found to be off by an average of 4 ± 5.3 (range of 1-17 bpm). When measured exercise HR was below the targeted zone, HR was found to be off by an average of 6 ± 3.0 (range of 1-11 bpm).

DISCUSSION

The overall results of the current study suggest that even when heart rate-based training zones are determined based on PMHR versus MMHR, the majority of the time (82%) subjects are in the correct zone. When subjects exercise HRs did not fall within their PMHR zones, their HRs were not off by a large range and only off by one zone. Subjects whose MMHR was higher than their given PMHR zones were only outside of the target zone by an average of 3 ± 2.0 bpm (range of 1-7) and those whose MMHR were lower than their given PMHR, were only off by one zone and were under by an average of 4 ± 3.1 bpm (range of 1-8).

There was a relatively weak correlation ($r = 0.45$) between PMHR and MMHR. However, one limitation to consider is the age range of subjects in the current study. Subjects were all college-aged students (18-25 years). This resulted in a relatively narrow range of PMHR (190-194 bpm), compared with the larger range of MMHR (181-210 bpm). This narrow range of PMHR may have resulted in the low correlation between PMHR and MMHR. In contrast, a good correlation ($r=0.72$) was found between MMHR and PMHR in a study by Ricardo de Abreu et al. (2008). They used the equation proposed by Karvonen, Kentala, and Mustala (1957) and Tanaka, Monahan, and Seals (2001). Richardo de Abreu et al. (2008) included subjects ranging in age from 12 to 69, and the authors attributed the good correlation to the large sample size and the large age range of their subjects.

A possible explanation for the favorable results in the current study is that the range of heart rates needed to be within a particular zone were large. For instance, for a 21 year-old subject, PMHR would be 192 bpm. To be within zone 4 (80-89% of PMHR), HR could range from 153-170 bpm. The goal was to have subjects' HRs fall within the middle of each PMHR zone. Therefore, the target HR for this individual was around 162 bpm. This individual could be off by ± 9 bpm to be outside the zone.

Some subjects' heart rates were harder to stabilize within zones when the intensity increased or decreased. Additionally, some subjects respond quicker and some respond more slowly, usually depending on their physical fitness level. Most of the time, when subjects were not able to get in the target HR zone, their measured HR was either much higher or much lower than their PMHR.

In practice, for individuals who just cannot get their HRs to fall within specific zones, we advise using an RPE scale, such as the one used in this study (Appendix E), in conjunction with age PMHR. Tanaka, Monahan, and Seals (2001) suggests that often times PMHR equations can overestimate HRmax in young adults and underestimate HRmax in older adults, depending on the equation used. The use of an RPE scale may help keep individuals safe if they do have a much lower MMHR in comparison to a PMHR when using a PMHR equation.

In conclusion, the purpose of this study was to investigate the accuracy of heart rate-based zone training using the PMHR equation $207-0.7(\text{age})$ versus MMHR. It was hypothesized that there would be a significant difference in the ability of individual subjects to attain target HR zones based on their PMHR versus MMHR. Results from the current study suggest that for college-aged students (18-25 years), using PMHR to define

training zones is fairly accurate. The majority of the time subjects will be in the correct HR zone. However, for those who cannot attain specific zones, we advise the usage of an RPE scale in conjunction with an age PMHR equation.

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APPENDIX A
INFORMED CONSENT

Protocol Title: The accuracy of heart rate-based zone training using predicted versus measured maximal heart rate

Principal Investigator: Amanda Leonard
930 Copeland Ave. Apt #: 109
La Crosse, WI 54603
Phone #: (715) 412-1299

Purpose and Procedure

The purpose of this study is to determine the accuracy of heart rate-based zone training using predicted versus measured maximal heart rate.

My participation in this study will involve two separate exercise sessions to be conducted in the Human Performance Laboratory, located in Mitchell Hall. A minimum of 48 hours will separate the two testing sessions. During session one, I will complete a 35-minute exercise bout on a treadmill while wearing a chest strap that continuously monitors my heart rate. I must stay within specific heart rate-based zones determined by my predicted maximal heart rate ($PMHR=207-0.7[\text{age}]$). During the second session, I will perform a maximal incremental treadmill test. The test will start at a self-selected walking or running speed and a grade of 0%. Grade will then be increased every 2 minutes until I reach volitional exhaustion. During this test I will be required to wear a chest strap to measure heart rate and to breathe through a one-way mouth piece in order to measure my expired air.

Potential Risks

I will feel a considerable amount of fatigue during my maximal incremental treadmill test, and possibly during the 35-minute exercise bout on a treadmill. Additionally, engaging in any exercise involves a risk of injury and potential life-threatening complications. However, for apparently healthy, regularly exercising individuals such as myself, the risks are near zero. In the case of an emergency, individuals trained and certified in CPR, Advanced Cardiac Life Support and First Aid will be in the laboratory at all times to assist with any complications. Additionally, emergency equipment (AED) and protocols are in place in the laboratory where testing will take place.

Possible Benefits

One direct benefit to myself will be gaining knowledge about my maximal aerobic capacity, which is the best measure of cardiovascular fitness, and my maximal HR, which can aid in exercise prescription. Exercisers, athletes, and the general population may benefit by gaining knowledge regarding the accuracy of heart rate-based zone training using predicted maximal heart rate.

Rights & Confidentiality

My participation in this study is entirely voluntary. I have the right to withdraw from the study at any time without penalty.

I understand the results of the study may be published in the scientific literature or presented at professional meetings using grouped data only. The investigator and appropriate laboratory personnel will be the only individuals with access to my individual data.

Liability

Neither the investigator nor the University of Wisconsin-La Crosse is liable for any personal injury that may occur during testing, and by participating I understand this and accept all responsibility.

Questions

I have read the information provided on this informed consent form. I have been informed of the purpose of this test, the procedures, and expectations of myself as well as the testers, and have also been informed of the potential risks and benefits that may be associated with volunteering in this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

If I have other questions that arise I may feel free to contact the principle investigator, Amanda Leonard at (715) 412-1299 or the study advisor, Dr. John Porcari, a Professor in the Department of Exercise and Sport Science at (608) 785-8684. Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects at 608-785-8124 or irb@uwlax.edu.

Subject Name (printed)

Subject Signature

Date

Narrative Statement

1. The purpose of this study will be to determine the accuracy of heart rate-based zone training using predicted versus measured maximal heart rate.
2. Subjects will complete a PAR-Q and risk factor assessment form to screen for orthopedic and cardiovascular contraindications to exercise. Each subject will attend two testing sessions on separate days in the Human Performance Laboratory, located in Mitchell Hall. A minimum of 48 hours will separate the two testing sessions. During the first session, subjects will complete a 35-minute exercise bout on a treadmill in which heart rate (HR) will be continuously monitored using a radio telemetry (Polar Electro Oy, Port Washington, NY). The treadmill protocol will be divided into seven, 5-minute training zones based on the subject's individual predicted maximal heart rate (PMHR). Predicted maximal heart rate will be estimated using the Gellish et al. (2007) equation: $PMHR = 207 - 0.7(\text{age})$. The five intensity zones that will be used in this study are: Zone 1 = 50-59%; Zone 2 = 60-69% HRmax; Zone 3 = 70-79% HRmax; Zone 4 = 80-89% HRmax; and Zone 5 = 90-100% HRmax. Subjective ratings of perceived exertion (RPE) will be assessed at the end of each 5-minute segment using the Borg 6-20 scale.
3. During the second session, each subject will perform a maximal incremental treadmill test to determine HRmax, $VO_2\text{max}$, and ventilatory threshold. The test will start with a self-selected speed and a grade of 0%. Grade will be increased every 2 minutes by 2.5% until the subject reaches volitional exhaustion. During the test, HR will be measured using radio telemetry (Polar Electro Oy, Port Washington, NY) and $VO_2\text{max}$ will be measured using an AEI metabolic cart (AEI, Pittsburgh, PA). Ventilatory threshold will be determined using the v-slope and ventilatory equivalent method.
4. The approximate start date for this study is October 15, 2016, and the planned date for completion is June 1, 2017.
5. Subjects for this study will be 24 apparently healthy, physically active men and women between 18-30 years of age.
6. Not applicable
7. All subjects will provide written informed consent after they have had ample time to review the study protocol. Voluntary informed consent will be obtained from subjects at the University of Wisconsin La-Crosse in the Human Performance Laboratory in Mitchell Hall.

8. Information obtained from each subject will be kept in an Excel spreadsheet which will be saved on a confidential flash drive. In the event of any publication or presentation of the results of this study, only aggregate data will be presented.
9. Subjects may experience substantial fatigue from both the incremental treadmill test and the zone-based exercise session. As with any exercise, subjects may experience muscle soreness, pulled muscles, and/or fatigue. Subjects will be healthy, therefore, the risks of a cardiovascular complication is near zero. However, testing will be terminated if complications occur. The total time investment for each subject will be approximately 2 hours.
10. Risks to the subjects will be minimized since they will be regular exercisers who will be screened via a PAR-Q and risk factor assessment form. Heart rate will also be monitored continuously during all testing. There will be individuals trained and certified in CPR, Advanced Cardiac Life Support, and First Aid in the laboratory at all times to assist with any complications that may arise. Additionally, emergency equipment (AED) and protocols are in place in the laboratory where testing will take place.
11. The direct benefit to subjects will be gaining knowledge of their maximal aerobic capacity, which is the best indicator of one's fitness level, and their maximal HR, which can aid in exercise prescription. Exercisers, athletes, and the general population may benefit by gaining knowledge regarding the accuracy of heart rate-based zone training using PMHR.

APPENDIX B
PAR-Q & YOU

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of any other reason why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.

- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) _____

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

APPENDIX C
RISK FACTOR ASSESSMENT FORM

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

Assess your health status by marking all true statements

History

You have had:

- _____ a heart attack
- _____ heart surgery
- _____ cardiac catheterization coronary angioplasty (PTCA)
- _____ Pacemaker/implantable cardiac defibrillator
- _____ rhythm disturbance
- _____ heart valve disease
- _____ heart failure
- _____ heart transplantation
- _____ congenital heart disease

Symptoms:

- _____ You experience chest discomfort with exertion.
- _____ You experience unreasonable breathlessness
- _____ You experience dizziness, fainting, or blackouts
- _____ You take heart medications

Other health issues

- _____ You have diabetes
- _____ You have asthma or other lung disease
- _____ You have burning or cramping sensation in your lower legs when walking short distances
- _____ You have musculoskeletal problems that limit your physical activity.
- _____ You have concerns about the safety of exercise
- _____ You take prescription medication(s).
- _____ You are pregnant.

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Cardiovascular risk factors

- _____ You are a man older than 45 years.
- _____ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal
- _____ You smoke, or quit smoking within the previous 6 months.
- _____ Your blood pressure is >140/90 mm Hg.
- _____ You do not know your blood pressure.
- _____ You take blood pressure medication.
- _____ Your blood cholesterol level is >200 mg/dl.
- _____ You do not know your cholesterol level.

- _____ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).
- _____ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).
- _____ You are >20 pounds overweight

If you marked two or more of the statements in this section you should consult you physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise Program.

_____ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

Modified from American College of Sports Medicine and American Heart Association. ACSM/AHA Joint Position Statement: Recommendations for cardiovascular screening, staffing, and emergency policies at health/fitness facilities. *Medicine and Science in Sports and Exercise* 1998:1018.

APPENDIX D
DATA COLLECTION SHEET

Heart Rate-Based Zone Training Data Collection Sheet

Name _____

Date _____

Stage	Zone	Time	Speed	Grade	HR		RPE
1	1						
2	3						
3	2						
4	4						
5	2						
6	5						
7	2						

Heart Rate-Based Zone Training Data Collection Sheet

Name _____ Age _____ Ht. _____

Date _____ Wt. _____

Stage	Zone	Time	Speed	Grade	HR	RPE
1	1					
2	3					
3	2					
4	4					
5	2					
6	5					
7	2					

APPENDIX E

RATING OF PERCEIVED EXERTION SCALE

The Borg Scale

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

APPENDIX F
REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

Only 21% of adults met the U.S. physical activity guidelines in 2014 (Center for Disease Control and Prevention, 2014). This is very disheartening because the benefits of exercise are numerous and well-defined. Variety is often important in order for individuals to adhere to an exercise routine. One way to keep individuals interested in exercise is through heart rate-based zone training using predicted maximal heart rate (PMHR). The purpose of this paper is to review the literature on the benefits and recommendations of exercise, zone training, concerns associated with zone training, the history of heart rate maximum (HRmax), and equations used to predict HRmax.

Benefits of Exercise

The Physical Activity Guidelines Advisory Committee Report (2008) reports that there is evidence of an inverse relationship between exercise and premature mortality, cardiovascular disease, obesity, hypertension, stroke, depression and much more. Not only is there an inverse relationship between exercise and its benefits, there is also evidence of a dose-response relationship between physical activity and its health benefits (Kesaniemi et al., 2001). These include cardiorespiratory health, metabolic health, mental health, weight loss, reduced risk of abdominal obesity, musculoskeletal health, reduced risk of falls in older adults, reduced risk of colon and breast cancer, and overall increased well-being. Although weight loss is a health benefit resulting from regular physical activity, it is important to note that weight management or prevention of weight gain may require a higher level of physical activity than what is recommended by the American College of Sports Medicine (ACSM; Donnelly et al., 2009).

Recommendations of Exercise

The ACSM recommends that all adults aged 18-65 participate in a minimum of 30 minutes of moderate intensity, aerobic exercise on 5 days of the week, or 20 minutes of vigorous intensity, aerobic exercise on 3 days of the week (Haskell et al., 2007). The ACSM (2014) defines zones for the general population (Table 1) using either a percentage of HRmax or as a percentage of heart rate reserve (HRR) to define light, moderate, vigorous, and maximal intensity exercise.

Table 1. Training intensity zones (ACSM).

Intensity Zone	% HRmax	% HRR
Light	57-63%	30-39%
Moderate	64-75%	40-59%
Vigorous	76-95%	60-89%
Maximal	96-100%	90-100%

What is Zone Training?

Target heart rates (HR) are typically calculated to get individuals into different “training zones.” Training in specific HR zones is important for athletes to optimize their specific goals. The overload principle states an athlete who is exercising below a minimum threshold will not gain physiological results, including cardiorespiratory fitness (Garber et al., 2001). Training adaptations and improved performance will result from zone training by placing physiological stressors on the body. Generally, greater results will come from exercising at higher intensities. Training zones have been and continue to be defined by many different methods, including percent maximal oxygen consumption

(VO₂max), %HRmax, rating of perceived exertion (RPE), or metabolic equivalents (METs).

For athletes, defining zones is often done in five stages as first described by Edwards (1992). She defines five training zones based upon five different levels of intensity (Table 2).

Table 2. Training zones using % HRmax as defined by Edwards (1992).

Training Zone	% HRmax
Moderate activity	50-60%
Weight management	60-70%
Aerobic	70-80%
Anaerobic threshold	80-90%
Red-Line	90-100%

Zone training is also one of the latest trends in the fitness industry and is gaining popularity. One fitness approach that utilizes zone training and has gained popularity is Orangetheory Fitness (<http://www.orangetheoryfitness.com>). Maximal HR is estimated for new members based upon an assessment on physical activity level, age, gender, height, and weight. Five HR zones are then calculated based on this estimated HRmax. A HR monitor is strapped onto each member's chest so HR can be continuously monitored throughout an instructor led 60-minute workout. Heart rates are projected on a screen for members to see whether or not their HRs are falling within a given zone. The goal of Orangetheory Fitness is to have members working in zones 4/5, or at 84% HRmax or higher, for 12-20 minutes. The theory behind this is what Orangetheory Fitness refers to as excess post-exercise oxygen consumption, or EPOC, which is elevated after high intensity training. The Orangetheory website (<http://www.orangetheoryfitness.com>) states

that metabolic rate will be increased for up to 36 hours if a member trains in zones 4/5 for 12-20 minutes. Although the research agrees there is EPOC after an individual exercises, a review of research surrounding EPOC was completed and found there are many variables that effect the amount of time EPOC lasts following exercise (Laforgia, Withers, & Gore, 2006). Some of these variables include the meals consumed post-exercise, the individuals resting metabolic rate, exercise intensity, and exercise duration.

Stephen Seiler (2010) goes a step further in defining zone training by using blood lactate concentrations. He defines Zone 1 as low-intensity (<2 mM/L), Zone 2 as moderate-intensity (>2 mM/L and <4 mM/L), and Zone 3 is defined as high-intensity (>4 mM/L). Lactate accumulates in the blood with increased exercise intensity exercise (Robergs, Ghiasvand, & Parker, 2004). An athlete will perceive exercise exertion as “very hard” as lactate concentrations in the blood increase, reaching a point where exercise cannot be continued and this phenomena is known as “the burn” or the lactic threshold of training (Kravitz & Dalleck, 2005).

Seiler (2010) reviewed the literature on training intensity in the performance of endurance athletes. He found that a study undertaken by Esteve-Lanao, San Juan, Earnest, Foster, and Lucia (2005) analyzed HR records over the course of 6 months from eight distance runners. All subjects performed a treadmill test to obtain HRmax. They defined three zones: Zone 1 (light intensity, below VT), Zone 2 (moderate intensity, between VT and respiratory compensation threshold) and Zone 3 (high intensity, above respiratory compensation threshold). Subjects trained each week for 6 months using different combinations of these three zones. HR was continuously monitored during each training session. This study found that performance in endurance events improved as the

total amount of time training in low intensities increased. No correlation between the amount of time spent in high-intensity training (HIT) zones and race performance times were found.

Another study done by Fiskerstrand and Seiler (2004) examined how training intensity was prescribed in elite rowers. They specifically looked at 27 rowers and quantified the amount of time spent exercising in low-intensity training (LIT) zones and HIT zones. Findings from this study demonstrated a total increase in LIT over 3 decades and a total decrease in HIT. These changes in training led to a 10% increase in rowing performance. Seiler (2010) reports that other studies done by Guellich and Seiler (2010), Zapico et al. (2007), Sandbakk, Holmberg, Leirdal, and Ettema (2010), and Schumacher and Mueller (2002) found that LIT was more beneficial than HIT in endurance athletes. In conclusion, Seiler (2010) suggests that most long-term endurance benefits come from training at low-intensity. However, there may be small benefits from HIT close to competition.

The term high-intensity interval training (HIIT) is often used interchangeably with the term Tabata. Tabata is a specific HIIT regimine that incorporates short bouts (20 seconds) of heavy exertion followed by short periods (10 seconds) of rest (Emberts, Porcari, Doberstein, & Foster, 2013). The term Tabata comes from a study conducted by Tabata et al. (1996). This study was a training experiment done on a cycle ergometer 5 times a week for 6 weeks. The control group completed bouts of exercise at 70% VO_2max for 60 minutes. The experimental group completed seven to eight bouts of Tabata at 170% VO_2max for 20 seconds with rest periods of 10 seconds. For both groups, VO_2max and anaerobic capacity were determined before and after the 6-week training

period. It was found that after 6 weeks of training at 70% VO_2max , control subjects VO_2max increased significantly, but their anaerobic capacity did not change. However, after 6 weeks, the HIIT group saw a significant increase in VO_2max and a 28% increase in anaerobic capacity. Overall, it is clear that exercising in specific zones leads to training adaptations and improved performance for many athletes.

Concerns of Zone Training

Predicted maximal heart rate is often used when defining HR zones. One concern when using PMHR is not knowing how closely it approximates an individual's true HRmax. It is hard to standardize training zones because of individual variability in HR and blood lactate concentrations (Seiler, 2010). In a review done on training intensity distribution in endurance athletes, it was found that often the amount of time an individual is actually in a HIT zone is underestimated. This could be due to a lag in the HR response to exercise. Heart rate monitors are very responsive, but it takes a while for HR to respond to what muscles are doing during exercise. Seiler (2010) also found that time spent in what a person may think is a LIT zone, is frequently overestimated.

History of Maximal Heart Rate

Measuring HR has been used for many years to evaluate how hard the heart is working before, during, and after exercise (Karvonen, Kentala, & Mustala, 1957). There are several ways to measure HR, some of which include auscultation with a stethoscope, palpation of the radial pulse, or by means of HR monitors (American College of Sports Medicine, 2014). To measure HR using the auscultation method, the bell of a stethoscope should be placed on the left side of the chest, above the sternum and nipple. To measure HR using palpation, the radial artery is used and can be located on the thumb-side of the

wrist. Heart rate monitors using radiotelemetry have been proven to be reliable provided there are no outside electrical interferences (American College of Sports Medicine, 2014). Heart rate is also used in a variety of clinical settings for exercise prescription. Exercise prescription is often recommended using a percentage of HRmax (e.g., 60-80% of HRmax) (American College of Sports Medicine, American Heart Association, 2007).

Maximal HR can be determined by performing a number of exercise protocols. The best way to determine HRmax is with a maximal exercise test. An individual is at their HRmax when intensity or the workload of an exercise is increased, but their HR does not increase any further (Edwards, 1992). One of the most commonly used treadmill protocols is the Bruce protocol. The Bruce protocol incorporates changes in speed and grade every 3 minutes to elicit a maximal effort (American College of Sports Medicine, 2014). However, many times it is not feasible to perform a graded maximal exercise test (GXT), and maximal testing can present risks among elderly, sick, or sedentary individuals. In cases where a GXT is not feasible or where a GXT is not available, HRmax can be estimated using equations (Robergs & Landwehr, 2002). Equations have been derived to predict HRmax, most of which are based on age. A meta-analysis done by Tanaka et al., (2001) found that HRmax decreases with increasing age and age accounts for ~80% of variance in HRmax. The most commonly used equation to predict maximal heart rate is $PMHR=220-age$ (Robergs & Landwehr, 2002).

Equations Used to Predict Maximal Heart Rate

Many times it may not be feasible to measure HRmax. Therefore, extensive research has been done and continues to be done in search of the most accurate equation to predict HRmax. There are many equations that have been developed over the years –

many having significant predication errors. Beginning as early as 1938, Robinson developed the equation $PMHR=212-0.77(\text{age})$ from his research data (Froelicher & Myers, 2000). Although many other equations have been developed, the most commonly used PMHR equation in exercise physiology is $PMHR=220-\text{age}$. Although this equation is a fairly good estimate and alternative to measuring HRmax in most individuals, the range of variation of HRmax in relation to age is quite large with a standard deviation of $\pm 10-12$ bpm (American College of Sports Medicine, 2000). Although this equation is often linked back to Karvonen et al. (1957), it is unclear where the original equation came from. In reality, the research done by Karvonen et al. (1957) was not designed to develop a PMHR equation. Karvonen et al. (1957) studied the relationship between training intensity and heart rate reserve (% HRR).

Extensive research has been done examining from which the most widely used PMHR equation originated. The 220-age is thought to be attributable to Fox et al. (1971) (Robergs & Landwehr, 2002). However, Fox et al. (1971) derived this equation by observation alone, from data compiled and put into a graph with a linear best-fit model (Froelicher & Myers, 2000). It is important to note that this equation was not based on original data, but instead was derived from a review of research on physical activity and heart disease (Robergs & Landwehr, 2002). A study was done in 2002 to try and replicate the equation presented by Fox et al. (1971) (Robergs & Landwehr, 2002). After plotting the Fox et al. (1971) data, Robergs and Landwehr (2002) used a line of linear regression and derived the equation $PMHR=215.4-0.9147(\text{age})$ and found a correlation coefficient (r) of $r=0.51$. This new equation did not match the $PMHR=220-\text{age}$ equation Fox et al. found in 1971. Therefore, Robergs and Landwehr (2002) suggest there was never

research to support this widely used PMHR equation. However, when comparing the two equations, there is only slight variability. The corresponding PMHR using Roberg's and Landwehr's equation at ages 20, 30, 40, 50, and 60 are 197, 188, 179, 170, and 161 bpm, respectively. Using the Fox et al. equation for the same ages give PMHR's of 200, 190, 180, 170, and 160 bpm. Although there are differences among the two equations, they do not differ by more than 3 bpm between the ages of 20-60. Robergs and Landwehr (2002) also reviewed 43 different PMHR equations to determine if a trend towards $PMHR=220-age$ was present. Of the 43 equations, 30 of them were used to derive a new PMHR equation. Thirteen of them were omitted because of non-healthy subjects. This study resulted in a new regression PMHR equation of $PMHR=208.754-0.734(age)$ with a correlation of $r=0.93$. The corresponding PMHR using the above equation at ages 20, 30, 40, 50, and 60 are 194, 187, 179, 172, and 165, respectively. The difference between this new equation and $PMHR=220-age$ is slightly greater, with the greatest difference of 6 bpm at age 20.

Tanaka et al. (2001) conducted a meta-analysis on 351 studies that included a total number of 18,712 subjects. Mean HRmax was obtained and a new PMHR equation was derived, $PMHR=208-0.7(age)$. Although this equation is becoming widely used in clinical studies and settings, it has a standard error of estimate of ~10 bpm (Sarzynski et al., 2013). When PMHR is calculated for ages 20, 30, 40, 50, and 60, a difference of 6 bpm is found at ages 20 and 60 when compared to $PMHR=220-age$. However, at age 40, the two equations give the same PMHR of 180 bpm. Tanaka et al. (2001) took their study to the next step by conducting a laboratory-based study on 514 healthy, non-smoking, non-medicated subjects to cross-validate their equation. Each subject performed an

incremental treadmill test to obtain their true HRmax. Treadmill grade was increased by 2.5% every 2 minutes until subjective exhaustion was achieved. The data from all 514 subjects was analyzed and a new equation, $PMHR=209-0.7(\text{age})$, was derived (Tanaka et al. 2001). These two equations are virtually the same, with a difference of only 1 bpm. Comparisons were made against other PMHR equations. Their results demonstrate that the widely used $PMHR=220-\text{age}$ equation often overestimates HRmax in young adults and underestimates HRmax in older adults.

A commonly used alternate equation was developed by Gellish and colleagues (2007). They examined data on maximal stress-testing measures from 132 individuals from a fitness center in Rochester, MN between the years of 1979 and 2003. A subjects underwent an average of 7 ± 2.3 yearly exercise tests (Gellish et al., 2007). Heart rate was monitored using electrocardiography. A total of 908 GXT were analyzed. It is important to note that subjects were not excluded if they had a history of smoking or drinking. However, subjects were excluded if they had previous heart disease, were taking medications that affected HR response, or had a positive electrocardiogram (ECG). Gellish et al. (2007) used a number of variables to try and predict HRmax including age, sex, body mass index (BMI), and resting heart rate. The findings confirmed no significant difference in HRmax between men and women and suggested age as the only independent variable when compared to the dependent variable of HRmax. The resulting equation was $PMHR=207-0.7(\text{age})$. The major advantage of this equation is that the standard deviation is $\pm 5-8$ bpm, whereas the standard deviation of the equation by Fox et al. (1971) is $\pm 10-12$ bpm (ACSM, 2014).

Concerns with Using Predicted Maximal Heart Rate

Equations used to predict HR_{max} are needed, especially in the clinical setting. Exercise physiologists use PMHR equations to get their patients to at least 85% of PMHR while administering a GXT, in order to determine if a significant effort was achieved. They look for drops in HR, ST depression on ECG, and signs and symptoms of chest pain that suggest the heart is not getting an adequate supply of blood (Kolata, 2001). If the GXT is stopped too soon because of an underestimated PMHR, diagnoses may be missed. On the other hand, if PMHR is overestimated, the patient may be put in danger.

In a study done by Jain, Nkonde, Lin, Walker, and Wackers, (2011) 306 patients were referred for symptom-limited treadmill tests. All of the patients were either suspected of having coronary artery disease (CAD) or had known CAD. Predicted HR_{max} was determined for each subject using $PMHR = 220 - \text{age}$. Of the 306 patients, 211 (69%) exercised 3.5 ± 1.9 minutes after their 85% PMHR was met. Three-hundred patients had abnormal ECG results. At 85% PMHR, 144 (47%) patients had an abnormal ECG, whereas at true peak HR_{max}, 232 (76%) patients had an abnormal ECG (Jain et al., 2011). Eighty-eight more patients had an abnormal ECG simply because they exercised to true peak HR_{max}. Therefore, Jain et al. (2011) demonstrates PMHR equations can and do underestimate an individual's true HR_{max} and that the widespread clinical practice of stopping at 85% PMHR may miss 1/3 of the abnormal ECG findings.

It is thought that Fox et al. (1971) likely included subjects in their study who had CVD and smoked, or were prescribed cardiac medications (Sarzynski et al., 2013). Heart rate maximum was influenced by these variables, regardless of age. The validity of $PMHR = 220 - \text{age}$ has been challenged by many other studies that have found the decay in

HRmax to be 3-5% per decade, whereas the equation of $PMHR=220-age$ suggests a decline of 5-7% per decade (Gellish et al., 2007). Again, these findings suggest $PMHR=220-age$ underestimates HRmax in older adults.

Unfortunately, it is highly unlikely an equation can be derived that works perfectly for every individual. There is a great deal of variability from person to person, based on things such as age, gender, and medical diagnoses, among others. Tanaka et al. (2001) report even among individuals of the same age, true HRmax can differ by upwards of 20-30 bpm. He also concluded that gender and physical activity level were not significant variables when predicting HRmax. Whaley, Kaminsky, Dwyer, Getchell, and Norton (1992) suggest HRmax greatly depends on factors such as lifestyle and physiology. On the other hand, Sarzynski et al. (2013) found that BMI, ethnicity, and current fitness levels are important variables when using prediction formulas. With so much controversy, it is clear that much more research is needed on PMHR equations.

Summary

According to the CDC, many adults are not meeting the recommended amounts of physical activity. In hopes of creating an exciting and new exercise routine, many individuals and fitness center are implementing heart rate-based zone training using PMHR into their workout. One example of a fitness approach that implements zone training is OrangeTheory Fitness. As we have seen, there are many benefits that can come from zone training, however there is a need for much more research on zone training using PMHR compared to MMHR.

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