Prediction of heart rates on a ropes course from simple physical measures

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In the past few years, at least six people in the United States have died from heart attacks while on high ropes courses or climbing towers as part of EBTD or CAT programming (Miner, 1991, Siewers, 1992). No negligence was found on the part of program providers (response was quick and appropriate). All fatalities were older males (over 50), who may well have expired from less strenuous undertakings later on, had they not unfortunately died during the adventure experience.

Heart attacks in people over the age of 40 are usually caused by coronary arterial disease (clogging of the heart's major arteries) brought on by various cardiovascular factors. Heart attacks in people under this age are typically attributed to a congenital defect. In both instances, exercise intensity is a key contributing factor. Rapid increases in heart rates or high sustained heart rates are often triggers that set off the cardiac arrest.

For the uninitiated, four types of heart rates are important to consider: resting, basal, maximum and target. Resting heart rate is the minimum number of beats per minute that the heart makes when the body is fully at rest (before getting out of bed in the morning not having responded to a wake-up alarm). Basal heart rate is the best estimate of resting heart rate. It is usually gained by having the individual sit still for five minutes before taking a pulse and counting beats per minute.

Maximum (age adjusted) heart rate is the highest number of beats per minute that healthy individuals should not exceed during exercise. It is a theoretical value obtained by subtracting one's age from a constant of 220. By way of example, a 40-year-old would have a theoretical maximum heart rate of (220 – 40 =) 180 beats per minute. However, in practical terms, the most a person should ever reach is about 90 percent of their age-adjusted maximum heart rate. For the 40-year-old example, this would be (180 X .90 =) 162 beats per minute.

Target heart rate is the lowest number of beats per minute that healthy individuals should surpass during exercise in order to attain a training effect on their cardiovascular system. It is calculated by subtracting resting heart rate from the maximum heart rate, multiplying the outcome by 60 percent and adding back the resting heart rate. The same 40-year-old, with a resting heart rate of 70 beats per minute, would have a recommended target heart rate of ([180 – 70] x 0.60 + 70 =) 136 beats per minute. For this example, the individual's heart rate should be maintained between 136 (target minimum) and 162 (target maximum or 90 percent of age adjusted maximum) beats per minute in order to obtain an aerobic benefit, without causing injury to the cardiovascular system in normal healthy individuals. This individual should not train their system above 162 beats per minute, but occasionally heart rate could surpass this recommended limit for a short period of time.

In her seminal work on university students engaged in rock climbing, rappelling, and ropes course elements, such as the Pamper Pole and Zip Line, Bunting and her colleagues (Bunting, Little, Tolson & Jessup, 1986; and Little, Bunting & Gibbons, 1986) have discovered average heart rates in excess of 200 beats per minute for some activities! These very high heart rates "can be explained by appealing to one's normal respect for heights and the anxiety associated with backing over the edge of a 30-foot-high cliff" (Bunting, Little, Tolson & Jessup, 1986: 19) or walking out onto a high ropes course element with 20 feet of open air underneath.

Furthermore, a majority of subjects had heart rates well beyond the target limit — "all but three subjects achieved this threshold of intensity level on each of the high ropes course events...both physical exertion and emotional anxiety contributed to the observed heart rate responses...stress inducement for the Pamper Pole was greater than [for] the other four events" (Little, Bunting & Gibbons, 1986: 39). Bunting and colleagues found these extremes for young, healthy and active individuals. What about older, less fit or sedentary peo-

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ple typical of the corporate populations mentioned earlier?

Pupose

The intent of this study was three-fold. The first purpose was to identify the highest heart rates attained on the ropes course for a corporate population. The second purpose was to examine the relationships between these highest heart rates and other easily obtained physical measures (basal heart rate, blood pressure, height, weight, body girths, cholesterol, maximum number of push-up and heart rate after briskly walking a mile). The third and final purpose was to be able to predict the expected highest heart rates from these physical measures by means of a linear regression equation. Such an equation would enable those adventure programs, who were concerned about particular individuals' cardiac risks, to input their easily obtained physical measures into this equation and thereby calculate their expected heart rate information. This technique would be one screening option available to adventure programs. No attempt is being made to suggest that this procedure must be followed for everyone who steps onto a ropes course.

Methodology

Subjects in this study were employees of a Canadian financial company, who volunteered to participate in the research study. Eight groups of 12 subjects engaged in a four-hour ropes course experience, held outdoors over four days in late March, 1994. The first hour involved collection of basic physical measures. The next three hours were spent preparing for, participating in, and processing from a high ropes course experience.

Physical measures were conducted in a university physiology laboratory. Basal heart rate was taken sitting down after a period of rest. Blood pressure was taken by sphygmomanometer cuff and stethoscope. Height was measured against a wall chart. Weight was measured on an analog floor scale. Body girths were taken by tape measure around chest and waist. Cholesterol (in a drop of blood) was analysed by a Reflotron spectrophotometer. Push-ups (used to indicate upper body strength, a very important consideration for ropes courses) were conducted to a metronome: one push-up every two seconds until exhaustion was reached. The Rockport walking test (time to briskly walk a mile with heart rate recorded afterwards) was used as a measure of sub-maximal oxygen uptake (an indicator of aerobic fitness). The benefit of this test is that the walking pace can vary among subjects, because the time to cover the distance and the heart rate upon completion are the two critical variables. Therefore, people can walk at their own brisk pace. Furthermore, this test requires no complicated or expensive physiological monitoring equipment. Likewise, the test does not require the subject to run, swim or bike (as in other sub-maximal stress tests with treadmills, current pools, or bicycle ergometers). The Rockport walking test is a valid and reliable measure that can be utilized by any supervising adventure practitioner not trained in exercise physiology (Dolgener, Hensley, Marsh & Fjelstul, 1994).

In addition to completing the standard research, medical and legal forms, subjects also completed the Physical Activity Readiness—Questionnaire (PAR-Q). The PAR-Q asked several questions related to health history, cardiac concerns, back problems and other risk factors. Subjects who answered affirmatively to any question were encouraged to seek advice from their physician prior to participating. Only one subject was restricted from the study for suspected health reasons.

The high ropes course was experienced in a series of connected outdoor elements built among six 40' utility poles arranged in a circle. Ten elements were used: Two Line Bridge (walk across a horizontal cable suspended 20' off the ground with a horizontal rope for a handhold); Beam Walk (walk across a horizontal utility pole 20' off the ground without any handholds); Criss Cross (walk across a horizontal rope suspended 20' off the ground with a handhold rope shaped like a "V" and no hand holds at the center); Heeby Jeeby (transfer from one rope to another suspended 30' off the ground; where the ropes are suspended in the shape of an "X" meeting at the center); Swinging Log (walk across a freely moving log that swings in all directions and is suspended horizontally 30' off the ground without any handholds); Tension Traverse (walk on a "tight cable" backwards suspended 30' off the ground with a "slack rope" attached only at one end and as the only handhold); Burma Bridge (walk across a "slack cable" with two parallel "tight ropes" for handholds 30' off the ground); Multivine (walk on "tight cable" 20' off the ground using vertically suspended hand lines; like Tarzan swings from vines, but with feet walking on the cable); Pamper Platform (climb a utility pole and stand on a wide platform, jump to catch a trapeze bar); and Pamper Pole (similar to platform, but jump from standing atop a narrow 25' utility pole).

The initial eight elements were completed utilizing static transfer systems (self-clipping of two safety lines onto an overhead steel cable), while the latter two used a dynamic belay system (a pair of safety ropes running through friction devices and controlled by others). Subjects worked in partnerships: while one person was on the course, the other was on the ground providing verbal support and either supervising static transfers between elements or belaying the partner. Subjects wore Polar Heart Rate Telemetry Systems. A band around the chest monitored their heart rates and time intervals, then transmitted these cardiac data to a wrist watch, which recorded the information for later retrieval.

Results

Since the ropes course and research were both conducted under a "challenge by choice" ethic, a few subjects declined to go up on the high ropes when their turn came. Some others chose not to have certain physical measures taken and many were unable to attend their scheduled session due to last minute work conflicts taking the priority. A total of 68 subjects (36 males and 32 females) completed all aspects of the study. Table 1 listed the ranges, averages and standard deviations for the physical measures conducted on these subjects.

Table 1: Descriptive statistics for physical measures (n=68)

HEALTH MEASURE	MINIMUM	MAXIMUM	AVERAGE	STD DEV
Age (years)	19	53	32.3	8.0
Basal HR (beats / min)	52	108	80.5	12.6
Systolic BP (mm of Hg)	100	180	123.1	12.7
Diastolic BP (mm of Hg)	50	110	78.1	9.7
Height (meters)	1.24	1.99	1.70	0.13
Weight (kilograms)	43.0	112.5	71.7	16.5
Chest Girth (meters)	0.285	1.205	0.877	0.144
Waist Girth (meters)	0.310	1.680	0.833	0.179
Cholesterol (mmol / liter)	2.59	8.24	4.64	1.22
Push-ups (every 2 sec)	5	60	21.8	9.9
Rockport HR (beats / min)	72	160	117.9	20.6
Rockport Time (minutes)	12.33	15.75	14.33	0.89

(n=36 males)

HEALTH MEASURE	MINIMUM	MAXIMUM	AVERAGE	STD DEV
Age (years)	19	51	31.2	7.9
Basal HR (beats / min)	52	102	76.9	11.4
Systolic BP (mm of Hg)	102	150	125.8	11.2
Diastolic BP (mm of Hg)	60	110	80.0	9.8
Height (meters)	1.24	1.99	1.77	0.15
Weight (kilograms)	54.5	112.5	83.1	12.4
Chest Girth (meters)	0.68	1.205	0.960	0.101
Waist Girth (meters)	0.655	1.155	0.906	0.108
Cholesterol (mmol / liter)	2.59	8.24	4.71	1.36
Push-ups (every 2 sec)	5	50	22.5	9.2
Rockport HR (beats / min)	80	152	111.4	18.1
Rockport Time (minutes)	12.35	15.53	14.27	0.85

(n=32 females)

HEALTH MEASURE	MINIMUM	MAXIMUM	AVERAGE	STD DEV
Age (years)	22	53	33.5	8.1
Basal HR (beats / min)	52	108	84.6	12.9
Systolic BP (mm of Hg)	100	180	120.0	13.8
Diastolic BP (mm of Hg)	50	90	76.0	9.4
Height (meters)	1.55	1.73	1.63	0.05
Weight (kilograms)	43.0	92.3	58.9	9.7
Chest Girth (meters)	0.285	1.080	0.784	0.128
Waist Girth (meters)	0.310	1.680	0.750	0.207
Cholesterol (mmol / liter)	2.59	6.90	4.57	1.07
Push-ups (every 2 sec)	8	60	21.0	10.7
Rockport HR (beats / min)	72	160	123.9	21.5
Rockport Time (minutes)	12.33	15.75	14.41	0.95

This middle-aged sample had average basal heart rate and blood pressure measures that were representative of the general population. Height, weight and other body measures were also typical of the general public. Cholesterol measures were found in all categories from low to high risk. Times and heart rates for the Rockport Walking Test were within national normative ranges. Ranges for all measures were broad enough to enable wide coverage of any predictive equation which might develop. Comparative variances (from standard deviations) were homogeneous and distributions for these measures met normality assumptions for further inferential analysis.

The first purpose of the study was to identify the highest heart rates attained during a ropes course experience. Subjects' highest heart rates attained ranged from 126 to 197, with an average (standard deviation) of 167.1 (16.7) beats per minute. While these heart rates came close to the 200 mark of Bunting and colleagues, this study's average was somewhat lower than what they had reported. Nevertheless, this range of heart rates is sufficient to predict targets and maximums.

The second purpose of the study was to examine the relationships between these heart rates and other easily obtained physical measures. Table 2 demonstrated the correlations among the measures taken in this study.

Strong correlations ($r > + 0.7$) were noted among measures of waist girth and weight, and of waist girth and chest girth.

Table 2: Correlation matrix for all physical measures (n=68)

	Age	BasHR	SysBP	DiaBP	Height	Weight	Chest	Waist	Chol	Push	RckHR	RckT	HHRA
Age	1												
Basal HR	-0.06	1											
Systolic BP	0.17	0.09	1										
Diastolic BP	0.19	0.23	0.47	1									
Height	-0.29	-0.04	0.15	0.07	1								
Weight	-0.10	-0.17	0.34	0.29	0.55	1							
Chest Girth	-0.03	0.00	0.32	0.34	0.40	0.75	1						
Waist Girth	-0.06	0.07	0.31	0.30	0.32	0.54	0.83	1					
Cholesterol	0.08	0.16	0.14	0.11	-0.01	0.23	0.29	0.29	1				
Push-ups	0.02	-0.08	0.00	-0.24	0.10	-0.11	-0.06	-0.10	-0.27	1			
Rockport HR	0.05	0.50	-0.18	0.04	-0.25	-0.10	0.09	0.20	0.33	-0.24	1		
Rockport Time	0.06	-0.06	0.10	0.04	0.00	-0.05	-0.22	-0.22	0.08	-0.08	-0.25	1	
Highest HR Attained	-0.22	0.27	0.05	0.20	-0.18	0.02	0.06	0.10	0.12	-0.04	0.42	0.06	1

Moderate correlations ($+0.3 < r < +0.7$) were present for systolic BP and diastolic BP, for basal HR and Rockport HR, for Cholesterol and Rockport HR, and in a cluster for various combinations of weight, chest girth, or waist girth with systolic BP, diastolic BP or height. The remaining relationships had weak correlations ($+0.3 > r$). As one might expect, the heart rates and blood pressures are closely related, as are the indirect measures (height, weight, chest girth or waist girth) of body size and percentage of body fat. These correlations are indicative of a sedentary corporate population. The zero-order correlations indicate that ages, basal heart rates and especially Rockport heart rates are all probably good predictors of the highest heart rates attained on a ropes course by this corporate sample.

The third purpose of the study was to predict highest heart rates from the prior physical measures by means of a regression equation. Several analyses were explored for all subjects and separately for females and males. The female equation was not significant. Only the analysis for males proved to be significant. Table 3 showed the stepwise regression sequence (F-enter set at 4.0, $p < 0.5$) used to create this equation for males.

In combination, five measures were effective predictors of highest heart rate attained. In order of contribution strength, they were Rockport heart rate (after one mile walk), age, Rockport time (to walk the mile), height, and girth ratio (chest girth divided by waist girth). According to the B coefficients, lower values on the Rockport measures (indicating greater fitness) correlated with lower heart rates attained. In addition, individuals who were younger, shorter and less fit tended to attain higher heart rates on the ropes course as indicated by the regression equation.

An example is presented using the real values of one of the researchers to show how the formula can be

Table 3: Stepwise regression predicting highest heart rates attained for males (n=36)

STEP	MEASURE	R	R-sq	F-test	B-coeff	F-enter/remove
#1	Rockport HR	0.51	.256	11.4	+ 0.521	20.5
#2	Age	0.64	.405	10.9	– 1.039	13.2
#3	Rockport Time	0.71	.499	10.3	+ 5.818	5.9
#4	Height	0.76	.573	10.1	–35.226	5.6
#5	Chest ÷ Waist	0.80	.634	10.0	–68.106	4.8
	INTERCEPT				+192.731	

PREDICTIVE REGRESSION EQUATION:

Highest HR Attained = 192.731 + 0.521(Rockport HR) – 1.039(Age) + 5.818(Rockport Time) – 35.226(Height) – 68.106(Chest ÷ Waist)

EXAMPLE (using data points of researcher):

Highest HR Attained = 192.731 + 0.521(120) – 1.039(35) + 5.818(13.9) – 35.226(1.80) – 68.106(1.04 ÷ 0.93)
= 192.731 + 62.520 – 36.365 + 80.870 –63.407 – 76.161
= 160.188 Chest ÷ Waist = 1.04 ÷ 0.93 = 1.12

Actual HR on ropes course = 150 beats per minute (error is 9.4% over-estimated)

applied. The predicted value is only off by 9.4 percent (10 beats per minute) and the error is one of over-estimation. Obviously, erring on the side of caution is desirable.

Conclusions

In this study, the highest heart rates for a corporate population, attained on the ropes course, ranged from 126 to 197. Aside from moderate to strong correlations found between both blood pressure measures or both heart rate measures and among all body measures, the highest heart rates attained were well correlated with other heart rate measures and the subject's age. While a predictive equation was not generated for females, the equation for males included 6 variables (5 regression steps) with a combined correlation coefficient of R=0.8 and 64 percent explained variance.

Programs interested in applying this equation as a possible pre-screening procedure for male clients they think might be candidates for a heart attack are encouraged to use this formula:

1) Obtain the client's age (rounded to the nearest year), height (in meters), chest girth (in meters) and waist girth (in meters).

2) Time (in minutes, with seconds expressed as fractions of a minute) how long it takes him to briskly walk one mile on level ground.

3) Take the pulse of the client immediately after finishing this mile walk by counting his pulse for fifteen seconds (multiply by four to get number of beats per minute).

4) Take these six values and plug them into the regression equation presented in this research. First, divide chest girth by waist girth to get a girth ratio. Second, multiply this girth ratio and the other four values by their respective coefficients. Third, sum these products (taking care to correctly include their positive and negative signs), along with the starting constant (192.731).

5) The resulting answer is the predicted highest heart rate that he may attain on a ropes course (but this prediction will not be perfect).

6) If this answer is greater than the upper limit of target heart rate for this client (90 percent of 220 minus age), then he should be advised to get medical clearance or be discouraged from further participation.

The authors of this research believe that this approach should not take the place of medical screening procedures for anyone who clearly demonstrates a history of risk factors (smoking, obesity, high blood pressure, sedentary lifestyle, hereditary coronary heart disease, etc.). Additionally, this regression procedure can be an inexpensive and simple intermediary step to identify prospective problematic individuals (who might not show these factors), prior to sending all suspects for a maximum exercise or stress test. One of the limitations of this study was the exclusion of subjects who were clearly at risk of a heart attack. Future research ought to replicate and extend this study for subjects with coronary risk factors and may also concentrate on developing a regression formula for females.

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References

Bunting, C. J., Little, M. J., Tolson, H. & Jessup, G. (1986). Physical fitness and eustress in the adventure activities of rock climbing and rappelling. *The Journal of Sports Medicine and Physical Fitness, 26*(1), 11-20.

Dolgener, F., Hensley, L., Marsh J. & Fjelstul, J. (1994). Validation of the Rockport Fitness Walking test in college males and females. *Research Quarterly for Exercise and Sport, 65*(2), 152-158.

Little, M. J., Bunting, C. J. & Gibbons, E. S. (1986). Heart rate responses to high ropes course events. *The Texas AHPERD Journal, 55*(10), 38-42.

Miner, T. (1991). Safety issues for experience-based training and development. *Journal of Experiential Education, 14*(2), 20-25.

Siewers, R. D. (1992). *Cardiovascular stress in ropes course participation.* Paper presented at the 3rd ropes course symposium, Hamilton, Massachusetts.