INVESTIGATION OF INCREASING RUNNING CADENCE AS A MEANS OF DETERMINING EXERCISE INTENSITY FOR AEROBIC TRAINING USING A MINI-TRAMPOLINE.

ANWAR KHAN

DEPARTMENT OF PHYSIOLOGY

FACULTY OF MEDICINE

UNIVERSITY OF NATAL

DURBAN

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DECLARATION

I, Anwar Khan, do hereby declare that this study is my original work. It has not been submitted to any other institution in full or otherwise. In the course of this study I have used references from other publications which have been duly acknowledged.

Signature: ....

Date: 7/11/97 ....

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ABSTRACT

PURPOSE. Researchers who have studied the physiological response to trampoline rebounding have not investigated the effect of increasing running cadence on exercise intensity for aerobic training using a mini-trampoline. It was the aim of the current study to investigate the effect of both cadence and leg lift on exercise intensity whilst rebounding.

METHODS. Seventeen male subjects rebounded on a mini-trampoline at stride frequencies of 100, 120, 160 and 200 steps per min with the soles of the feet 15 cm above the rim of the trampoline. Furthermore, at 120 steps per min, they rebounded with the hips at 90 degrees of flexion. Each stage lasted 3 minutes with a rest of 1 minute between stages. Oxygen uptake and heart-rate were monitored throughout the exercise.

A symptom limited treadmill test was also carried out on each subject. For this test, each subject was requested to run on the treadmill at increasing intensities of speed and gradient. Six stages were carried out at 3 min per stage and a 1 min rest period in between stages. During the last stage the subjects were requested to continue running until they could not go on any further. Oxygen uptake and heart-rate was monitored throughout the exercise.

RESULTS. With increasing intensity of rebounding from 100 to 160 steps per min there were significant increases in heart-rate ($p < 0.05$), whilst the oxygen uptake remained constant. For stepping frequencies greater than 160 steps per min, there was a proportionate increase in heart-rate and oxygen consumption. Increasing the leg lift from 15 cm above the rim of the mini-trampoline to a hip flexion of 90 degrees while rebounding at 120 steps per min, substantially increases heart-rate and oxygen consumption ($p < 0.001$). Increasing the intensity of treadmill exercise showed a proportionate increase in all physiological parameters.

CONCLUSION. Increasing the running cadence between 100 to160 steps per min is not sufficient to elicit an increase in oxygen consumption despite apparent increases in heart-rate. Therefore heart-rate is a poor physiological marker of exercise intensity during trampoline exercise. In order to elicit an exercise intensity required for improvements in aerobic capacity, the running cadence must be in excess of 160 steps per min and the leg lift must be greater than 15 cm above the trampoline bed.

CHAPTER 1.

INTRODUCTION

Trampoline jumping or rebounding is used as a means of exercise by many people today, as a new activity to improve cardiorespiratory fitness. The introduction of the mini-trampoline which is small, portable and inexpensive and intensively marketed by advertisements claiming that "rebounding exercise is the most efficient and effective form of exercise yet devised by man", has increased the use of this form of exercise.

A review of the limited literature available on the subject of rebounding and the popular perception amongst the greater public suggests that it may have the potential to improve cardiorespiratory fitness. However, quantification of exercise intensity whilst rebounding is difficult, making exercise prescription for improvements of cardiorespiratory fitness difficult.

In order to establish an effective rebounding training programme several factors must be considered. These include the intensity of the exercise, the duration of the exercise session, the frequency of the exercise, the duration of the programme and the initial level of fitness of the individual. Exercise intensity has been established as the most important determinant of the effectiveness of an exercise programme (Casaburi,1994). In prescribing exercise, the intensity must be sufficient to result in cardiorespiratory improvements and an objective physiological variable should be used to monitor the intensity. Of the physiological markers of exercise intensity, heart rate, oxygen consumption (VO_2) and blood lactate levels, heart rate is usually chosen in a non-laboratory setting because it is easy to measure. This is further supported by the fact that the relative percentages of maximum oxygen consumption and the percentages of maximum heart rate are thought to be related in a linear manner regardless of gender, fitness level or age (Table 1).

Table 1. Relationship between percent max. VO_2 and percent max. heart rate.

PERCENT MAX. HR.	PERCENT MAX. VO_2
50	28
60	42
70	56
80	70
90	83
100	100

From Mc Ardle, Katch and Katch (1991).

This relationship can be established for an individual for a given task and then the maximum oxygen consumption can be estimated from the heart rate monitored during subsequent exercise. It is not known if a linear VO_2-HR relationship exists for increasing exercise intensity for trampoline rebounding.

Hence a study was designed to compare the heart rate and VO_2 relationship during trampoline rebounding at different cadences to that of treadmill running. Furthermore in an attempt to simplify the prescription of exercise using the trampoline, the effects of changing the step frequency and leg lift were investigated.

CHAPTER 2

LITERATURE REVIEW

2.1 REBOUNDING STUDIES.

A review of the literature reveals conflicting results. This could be partly due to inconsistencies regarding the definition of trampoline exercise and the absence of a standardised testing and or training protocol with regard to rebounding.

Prior to commencing with this study it is essential to define the terminology used with regard to trampoline exercise.

Rebounding, running, jogging and stepping on the trampoline means that there is alternate foot strike during the exercise. Furthermore each foot strike is counted individually.

Bouncing or jumping on the trampoline means that both feet are used simultaneously during the exercise. Hence, for this type of activity each landing on the trampoline is counted as one step or bounce.

The pioneering study of trampoline jumping was performed at the Biomechanical Research Division of the NASA-Ames Research Centre (Bhattacharya, McCutcheon, Shvartz, Greenleaf,1980). This study, in humans, investigated the body's acceleration, oxygen uptake and heart rate response during running and jumping on a trampoline. The reason for the study was to establish an acceleration profile that could be used in cardio-vascular and muscular conditioning programmes during space flight. The relationship between such acceleration and the metabolic cost involved with respect to oxygen consumption and heart rate was also determined.

In the above study, 8 men between the ages of 19 to 26 years were tested. They were first exercised on a treadmill at 4 different speeds (4.8 km / hr for 10 min; 8.1 km / hr for 8 min; 9.6 km / hr for 7 min; and 11.3 km / hr for 6 min). There was a 5 to 6 min rest in between runs. The trampoline protocol included a 5 min jump using both feet simultaneously at 18, 37, 75, and 100 cm above the trampoline bed with a 5 min rest in between jumps. Due to the height of the jumps required for the study, a regulation trampoline bed (2.74 x 4.56 m) made of nylon webbing supported by springs was used.

The measurements taken that are of relevence to the current study were pulse rate before and after exercising and oxygen consumption while exercising. The results of this study showed that there was a linear relationship between oxygen consumption and heart rate for both trampoline jumping and treadmill running.

Subsequent studies on rebounding were performed on a mini-trampoline. White (1980) carried out a training study on 60 overweight females. The subjects rebounded on a trampoline for 30 min sessions, 4 times per week for ten weeks at an exercise intensity producing a heart rate of 150 beats per min. He concluded from this study that rebounding resulted in changes in maximum aerobic power and in percentage body fat equal to that of training on a treadmill or stationary cycle. He reported a 12.8% loss of body fat (31.2% to 27.2%), or a 12.2 kg loss in body weight and an increase in VO_{2max} of 10.3% (30.4 to 33.9 ml .kg.$^{-1}$ min $^{-1}$). It is perhaps somewhat surprising that such a large percentage decrease in body fat occurred with a moderate exercise heart rate.

Katch, Villanacci & Sady (1981) carried out a study to determine the energy cost of rebound running. The purpose of the study was to investigate the energy cost and the heart rate response of rebound training and to make comparisons with other forms of aerobic exercises. In this study 12 sedentary subjects were tested. They ranged in ages from 19 to 56 years (mean 28 yrs, SD 10.5) and in body weight from 46 to 86 kg (mean 67.2 kg. SD 11.3). The testing procedure required the subjects to rebound run on a trampoline for 10 min. The subjects were asked to run at a self chosen pace as long as they maintained a "normal" rebound height. This protocol was based on a preliminary study of 25 subjects, that found when the subjects rebound ran at a self chosen pace, while maintaining a "normal" rebound height, the range of stepping was between 54 to 68 steps per min. From this I assume that each right and left foot strike was counted as one step. When the subjects were asked to either increase or decrease their stepping rate while maintaining the "normal" rebound height the frequency of stepping remained the same. In the light of this data they concluded that it was not necessary to control the stepping rate during the energy expenditure measurements. The average stepping rate achieved by the subjects was 60.4 ± 2.7 steps per min.

The results of the study showed that the average VO_2 of 1.2 l / min (17ml.kg.$^{-1}$min^{-1}) represented a 5.1 MET load which would place rebounding in the moderate exercise category (Taylor, 1960). The heart rate response indicated only moderate cardiac work, with the average heart rate recorded as 116 ± 12 beats per min. However, this heart rate is considerably lower than that reported in the study by White (1980).

Katch et al., (1981) calculated that by rebound running for 1200 minutes at a body weight of 86 kg the energy expenditure would be 9600 kcal (total kcal = 0.1141x - 1.8088 where x = body weight). The weight loss of 12.2 kg reported in the study by White(1980), represents a total kcal.of 94 153. Hence a discrepancy of 84 000 kcal exists between the actual observed weight loss and that which would have occurred by rebound running alone. Hence, Katch et al. (1981) calculated that of the 12.2 kg loss shown by White, (1980) 2.7 kg loss could have come from rebounding and the remaining 9.5 kg loss from diet or other activities.

In addition to the training studies done by White (1980) and Katch et al. (1981) three other studies have been published. These were by Evans et al. (1984), Gerberich et al. (1983) and Tomassoni et al. (1985). A summary of their findings is presented in Table 2.

Table 2. Comparison of rebounding training studies.

AUTHORS	SUBJECTS	PROGRAMME	INTENSITY	VO_2 MAX ml/kg/min
Gerberich et al. 1983	17 females 18-40 yrs	5x30 min / week for 12 weeks	70-85% HR.max	4.5% increase
Evans et al. 1984	26 females 18-35 yrs	3x20-40 min / week for 8 weeks	not reported.	minimal improvement
Tomassoni et al.. 1985	21 females 18-28yrs	3x 40 min / week for 8 weeks	75-85 % HRrmax	9% improvement

The training studies in Table 2 do not give any indication of how the intensity of the exercise was increased. Although the training heart rate data reported would appear to be sufficient to provoke a training effect, the improvement in $VO_{2\,max}$ appears to be minimal. This suggests that the heart rate may not be a true reflection of exercise intensity for rebounding on a trampoline.

Ballard, Dal Pozzo and Healy (1984) compared the rating of perceived exertion, energy cost and cardiovascular response to treadmill and mini-trampoline work. In this study 10 male subjects were required to walk for 10 min and then run for 10 min on each type of equipment. The stepping cadence was set for each subject at 4.0 mph (walking) and 6.5 mph (running) on the treadmill and were found to be a mean of 122.7 and 165.1 steps per min. The cadence determined from the treadmill protocol was achieved on the trampoline by the use of a metronome set at 122 and 164 steps per min respectively. The results showed that treadmill work was greater than mini-trampoline work during walking at the same cadence. The mean VO_2 response for the treadmill work, for walking was

22.4 $ml.kg.^{-1}min^{-1}$ and 18.49 $ml.kg.^{-1}min^{-1}$ on the mini-trampoline. The heart rate response was an average of 109.1 bpm on the treadmill and 100 bpm on the mini-trampoline. During running, treadmill work was also greater than mini-trampoline work. The mean VO_2 response was 41.9 $ml.kg.^{-1}min^{-1}$ on the treadmill and 20.62 $ml.kg.^{-1}min^{-1}$ on the mini-trampoline. The heart rate response was an average of 162.7 bpm for treadmill exercise and 109.3 bpm for mini-trampoline exercise.

The authors concluded that walking on the treadmill was equavalent to running on the trampoline. They therefore suggested that mini-trampoline work was to be used for persons of low exercise tolerance and for those whose cardiovascular system needed to be closely monitored.

Gerberich, Leon, McNally, Serfass and Bartlett (1990) systematically increased the work load of trampoline exercise in 17 subjects by increasing the stepping rates for bouncing with two feet together from 90 to 140 bounces per min and jogging with alternate feet from 105 to 205 steps per min. These protocols included six, 3 min stages. For bouncing, the rate was increased by 10 bounces at the end of each stage and for jogging by 20 steps. The rate of bouncing and jogging was regulated by the use of a metronome. Two maximal symptom-limited exercise treadmill tests were conducted one week apart on each subject using a modified Bruce protocol (i.e. 4 min per stage). Oxygen consumption and heart rate were monitored continuously throughout each set of exercises. For jogging activity it was demonstrated that the heart rate increased as the number of jogging steps increased, but, for bouncing activity a reverse effect was observed. The mean values for both heart-rate and VO_2 decreased during bouncing activity, but increased during jogging on the mini-trampoline. This study when compared to the one by Bhattacharya et al. (1980) shows that the height of bouncing on a trampoline may be responsible for the increase in heart rate and oxygen consumption. A summary of the results of heart rate and VO_2 response to bouncing and jogging on a mini-trampoline found by Gerberich et al. (1990) is tabled below.

Table 3. Summary of cardiovascular response to bouncing and jogging on a mini-trampoline.

	BOUNCING 90 to140 (jumps / min)	JOGGING 105 to 205 (steps / min)
HEART RATE bpm .	166 to 158	157 to 183
VO_2 l/min	1.52 to 1.19	1.36 to 1.55

In addition, the authors showed that a plateau of VO_2 was evident between the heart rates of 156 to 170 bpm during trampoline jogging.

A review of the results of energy cost studies done on rebounding show a wide range of differences between studies. Five such studies that were carried out were reviewed by Smith and Bishop (1988) are summarised in Table 4 .

Smith and Bishop (1988) argued that given the range of VO_2 from these 5 studies

(17 to 39.9 ml. kg. $^{-1}$ min $^{-1}$) and using the American College of Sport Medicine intensity recomendations of 50% $VO_{2\ max}$ rebounding exercise should provide intensities great enough to promote increases in cardiorespiratory fitness for participants with a wide range of values of $VO_{2\ max.}$

From the results shown in Table 4 it is interesting to note that the mean VO_2 is not being compared to exercises of the same intensity, in this instance, the same step frequency. Also, besides the study by Bishop et al. (1986) where the leg lift was maintained at 15 cm above the trampoline bed none of the other researchers maintained a constant leg lift while rebounding. This could be one of the reasons for large variations in energy cost shown in the studies in Table 4.

Table 4. Comparison of energy cost studies

AUTHORS.	SUBJECTS	STEP FREQUENCY (foot strike/ min)	MEAN VO_2 (ml/kg/min)
Katch et al. 1981	12	108-136	17
Cooter et al. 1983	19	160	23. 3
Gerberich et al. 1983	17	105	38.7
		205	47. 5
Ballard et.al. 1984	10	122	18. 5
		165	20. 6
Bishop et al. 1986	15	120	27.. 5

(Smith & Bishop 1988)

2.2 RELATIONSHIP BETWEEN HEART RATE AND VO_2 DURING EXERCISE.

When selecting the population for the study, the effect of age and gender on heart rate and VO_2 had to be considered. After age 25 years, $VO_{2\,max.}$ declines steadily at about 1% per year. At age 14 years difference between male and females is about 25% and about 50% at age 16 years. There are also certain factors to be considered when using heart rate as a variable to predict $VO_{2\,max.}$.

These include:

1) LINEARITY OF THE HEART RATE / OXYGEN CONSUMPTION CURVE.

Common tests to predict $VO_{2\,max}$ on a treadmill, bicycle or step make use of the essentially linear relationship between heart rate and oxygen consumption for various intensities of light to moderate exercises. However, at heavier work loads the oxygen consumption line curves in a direction that indicates a larger than expected increase in oxygen consumption per unit increase in heart rate.

2) SIMILAR MAXIMUM HEART RATE FOR ALL SUBJECTS

The standard deviation for heart rate for individuals of the same age is approximately 10 beats per minute (McArdle et al. 1991). Therefore the $VO_{2\,max}$ of a person with an actual maximum heart rate of 185 beats per min would be overestimated if the heart rate/oxygen consumption line was extrapolated to 195 beats per min. Maximum heart rate also decreases with age (220-age = predicted maximum heart rate).

3) MECHANICAL EFFICIENCY

Subjects with poor mechanical efficiency have relatively elevated heart rate and oxygen consumption at submaximal work loads. In these situations the prediction of VO_2 from the measured heart rate may be in error by the magnitude of the variability in mechanical efficiency.

CHAPTER 3.

PROCEDURE AND METHODS

3.1 SUBJECTS.

Seventeen healthy active male volunteers were enrolled in the study. Subjects gave their informed consent after the procedure of the study was explained to them.(Refer to Appendix 1). They were then allowed to practice on the trampoline and treadmill to familiarise themselves fully with both pieces of equipment and the breathing apparatus. The subject's height and weight were measured. The means of these values are listed in Table 5.

3.2 EQUIPMENT AND STUDY DESIGN

Prior to testing, the Mijnhardt Oxycon gas analyser was calibrated by introducing a certified gas mixture. The pneumotach was calibrated with a three litre automatic expiration.

It was not possible to randomise the order of the exercise protocols as the range of heart-rate for trampoline rebounding determined the workloads utilised during the treadmill protocol.

3.3 TRAMPOLINE PROTOCOL (Appendix 2)

Each subject was required to jog on the trampoline at a prescribed frequency of foot strikes per min and a leg lift raising the sole of the shoes 15 cm above the rim of the trampoline bed. A metronome was used to provide the required stepping frequency and a 15 cm marker and an observer were used to standardise the leg lift. The subject was connected to the mouthpiece of the Mijnhardt Oxycon Gamma gas analyser and a nose clip was used to ensure that there was no nasal breathing. The heart rate was monitored throughout using a Polar Sport Tester heart rate monitor which was strapped to the subject's chest.

The subject jogged at a frequency of 100, 120, 160 and 200 steps per min with the foot raised 15 cm above the rim of the trampoline. The subject jogged for three min at each stepping frequency and rested for one min between each bout of exercise. At the end of the 200 steps per min the subjects were allowed to rest for five min. They were then required to jog at a frequency of 120 steps per min bringing the hips up to 90 degrees of flexion for a further three min.

The heart rate was taken every 5 seconds. The oxygen consumption (VO_2), minute ventilation (Ve), and respiratory quotient (RQ) readings were recorded continuously and printed at the end of each session and averaged for the last 30 seconds of each exercise bout (Table 6).

3.4 TREADMILL PROTOCOL (Appendix 2)

After the trampoline exercise, the subjects were rested for a minimum of one hour before commencing the treadmill exercise. The subject was connected to the heart rate monitor and the gas analyser as before. Each subject was required to run for three min at five different intensities beginning at at 8 km / hr at zero gradient. The intensity was increased by keeping the speed constant, but increasing the gradient. The gradient was increased by 1.5% for the first five work loads. Between each work load the subjects were rested for one min. At the end of the fifth work load the subjects were rested for five min. They were then exercised at an intensity of 8 km / hr and a gradient of 7.5 %. At the end of each min the speed was increased by 1 km / hr until a speed of 10 km / hr was reached and then kept constant. The gradient was also steadily increased at the end of each min and continued to increase until the subjects could no longer continue exercising.

The heart rate was recorded at the end of the second and third min of each exercise bout. The peak heart rate was also recorded. The recordings were made continuously and printed at the end of the exercise. The VO_2 readings and the heart rate were averaged for the last 30 seconds of each exercise bout (Table 8). The PEAK values recorded at the end of the treadmill exercise were used to calculate the percentage of maximum of the variables for both treadmill and trampoline exercise.

Using the values of VO_2 obtained during both the treadmill and trampoline exercise, the energy cost of the work done was computed as follows:

Kcal = VO_2 x kcal equivalent (Appendix 3)

3.5 STATISTICAL ANALYSIS.

Mean and standard deviations were calculated for all variables for the different work loads. To determine the effect of workload, a one way analysis of variance (ANOVA) was used and if significant this was followed by post-hoc paired t-test between individual workloads corrected with a Bonferoni correction factor for the number of t-tests.

CHAPTER 4.

RESULTS.

The characteristics of the subjects are shown in Table 5.

Table 5. Subjects' characteristics

VARIABLE	RANGE	MEAN	SD.
Age, yr	17-24	20.8	2.0
Weight, kg	44-74	62.4	6.5
Height, cm	162.5-176.7	170.1	4.1

1) Results obtained from trampoline exercises.

The mean cardiorespiratory measures at different stepping frequencies during trampoline exercises (n = 17), are summarised in Table 6. The results in Table 6 are averages taken at the last 30 seconds of each workload. The 30 second averages were used for statistical analysis. When workloads were increased from 100 steps per min to 200 steps per min the heart rate progessively increased from 133 bpm to 167 bpm (25.6 % increase). The oxygen consumption, however, remained more or less constant for the initial three increases in workload. A significant increase in oxygen consumption only occurred once the workload was increased to 200 steps/min. This relationship between heart rate and oxygen consumption with increasing workloads for trampoline exercises is shown in Fig.1.

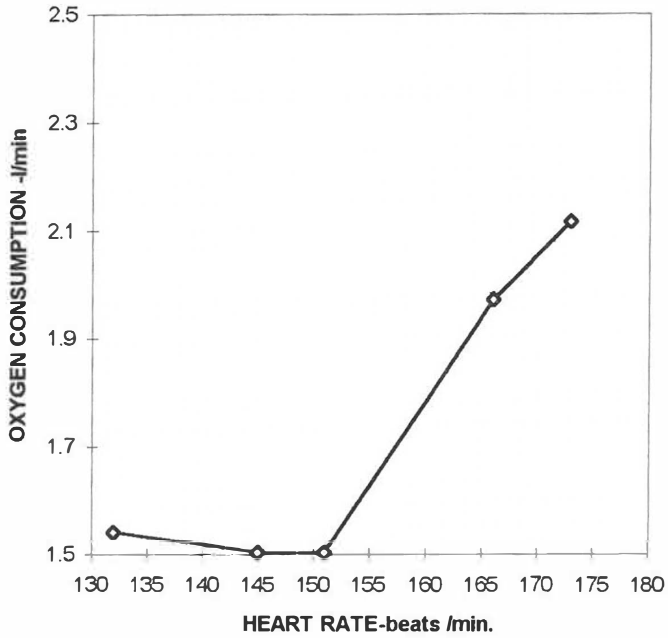

Fig. 1 Relationship between oxygen consumption and heart rate during trampoline exercises

Table 6. Mean cardiorespiratory measures at different stepping frequencies during trampoline exercises.

WORK LOAD	MEAN VO_2 ml. / min			Ve l./ min	RQ	MEAN HEART RATE bpm.		
STEPS / MIN	30 sec.	SD	% max			30 sec.	SD	% max
100	1542.9	351.5	47	30	0.84	132.9	17.6	66
120	1503	310.8	46	36.7	0.92	145.4	16.8	73
160	1540.2	246	47	40.1	0.91	151.3	18.2	76
200	1971.5	285.3	60	50.3	0.92	166.5	17.5	83
120 @ 90deg.	2116.9	264.6	64	52.2	0.96	173.8	14.3	86

Increasing the leg lift to 90 degrees of hip flexion while rebounding at 120 steps per min increases oxygen consumption, heart rate, ventilation and the respiratory quotient significantly ($p < 0.001$). Fig.2 shows the effect on oxygen consumption and Fig.3 the effect on heart rate.

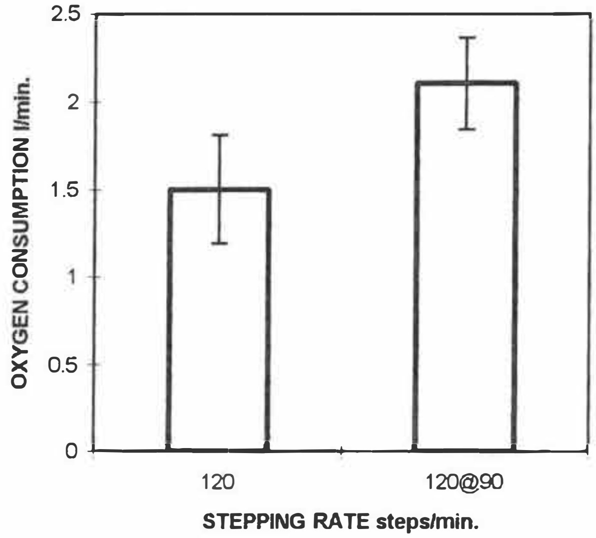

Fig.2 The difference in oxygen consumption with similar stepping rates but varying the stepping height during trampoline exercise

Table 7. Effect of stepping frequency: t-tests.

WORKLOAD STEPS /MIN	VO2 ml. /min 30sec	HEART RATE 30 sec. bpm
100 VS 120	N.S.	P <0.001
120 VS 160	N.S.	P <0.04
160 VS 200	P <0.001	P <0.001
120 VS 120/90	P <0.001	P <0.001

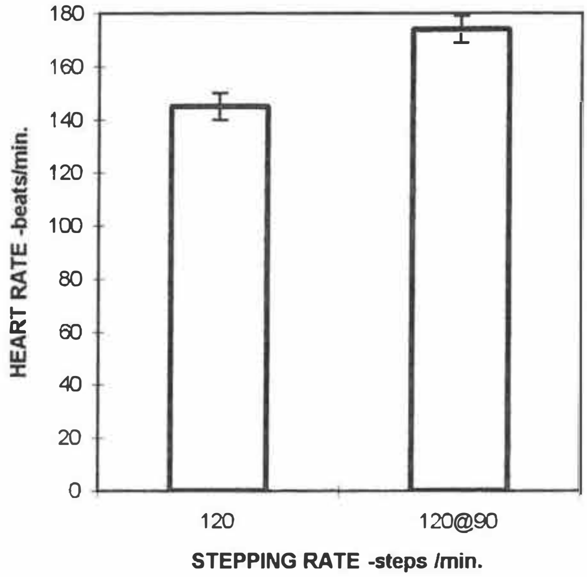

Fig.3 The difference in heart rate with similar stepping rates but varying the stepping height during trampoline exercise.

With increasing work loads during trampoline exercise ventilation increased progressively from 30*l* per min at 100 steps per min to 50*l* per min at 200 steps per min. In relation to this increase in ventilation, the oxygen consumption remained unchanged during the first three increases in workload (Fig.4). Therefore it is apparent that the ventilation is inappropriately high during the lower workloads of trampoline exercise and it reflects the same pattern observed in the relationship between heart rate and oxygen consumption (see Fig. 1). This is not the case for treadmill exercises which show a proportionate increase in oxygen consumption in relation to ventilation (Fig. 7).

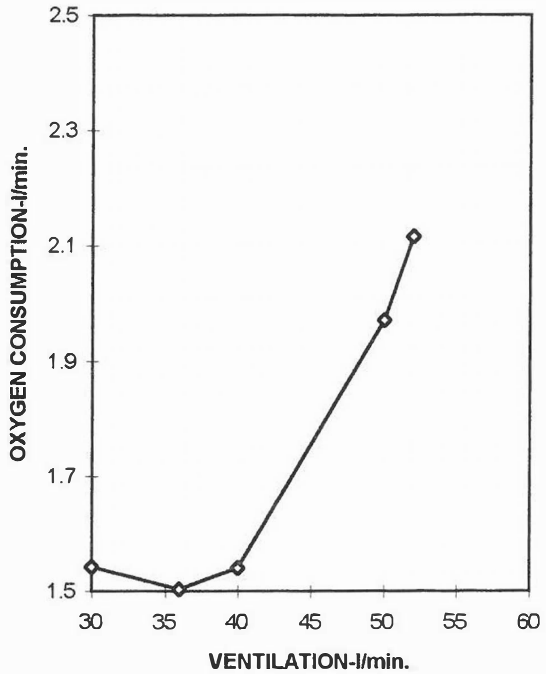

Fig. 4 Relationship between oxygen consumption and ventilation during trampoline exercises.

The energy cost results for trampoline exercise are shown in Fig.5 and that of treadmill exercise in Fig.8. For treadmill exercise there was a steady increase in energy consumed with increasing heart rate. However for trampoline exercises for the first 20 beats per min increase in heart rate there was less than 1 kcal per min of energy consumed. For the next 20 beats per min increase in heart rate the energy consumed increased by 3 kcal per min.

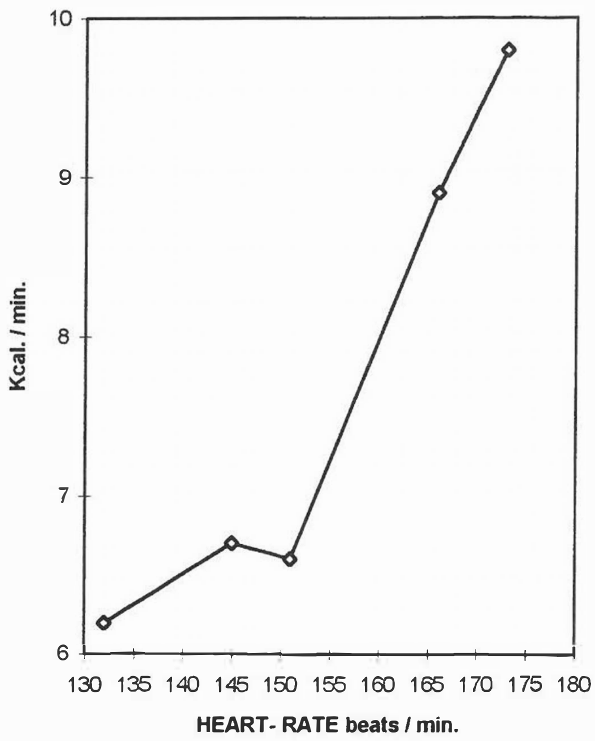

Fig. 5 Relationship between heart rate and energy consumed during trampoline exercises.

2) Results obtained from treadmill exercises.

The results for treadmill exercises (Table 8) show that for increasing workloads there is a proportionate increase in oxygen consumption, heart rate and ventilation. The relationship between heart rate and oxygen consumption during treadmill exercises is shown in Fig.6

Table 8. Mean cardiorespiratory measures during treadmill exercises.

WORK LOAD	VO_2 ml. / min			Ve l./ min	RQ	HEART RATE bpm.		
	30 sec.	SD	%max			30 sec.	SD	% max
1	1807.5	±158.7	55	35.2	0.78	143	±13.7	71
2	1972.9	±177.3	60	40.1	0.82	152.6	±15.4	76
3	2167.5	±226.9	66	44.1	0.84	160.4	±16.5	80
4	2414.8	±189.9	73	52.2	0.87	169.3	±16.6	85
5	2488.6	±189.9	76	55.5	0.86	179.5	±14.7	89
PEAK	3276.8	±447.1		93.8	1.08	199.4	±6.4	

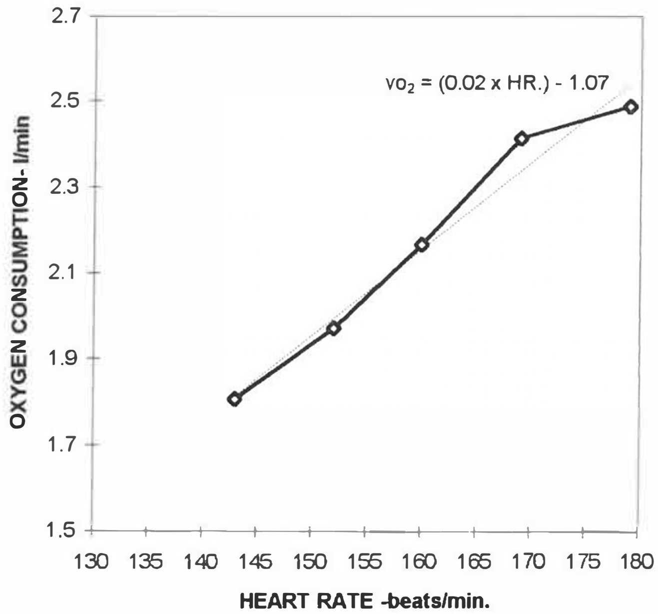

Fig.6 Relationship between oxygen consumption and heart rate during treadmill exercise.

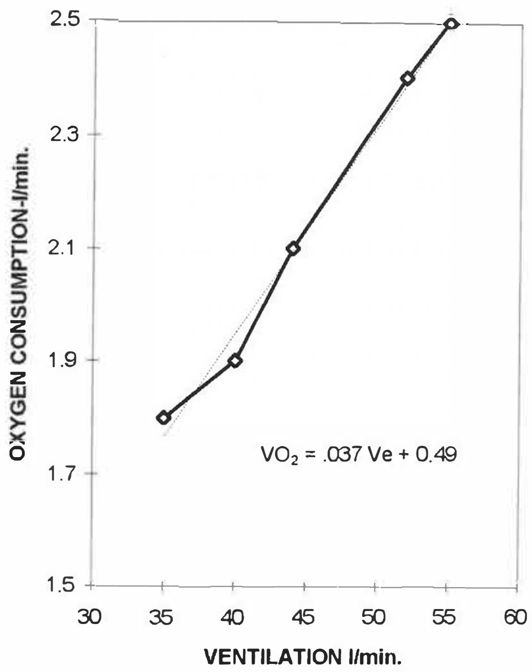

Fig.7 Relationship between oxygen consumption and ventilation during treadmill exercises

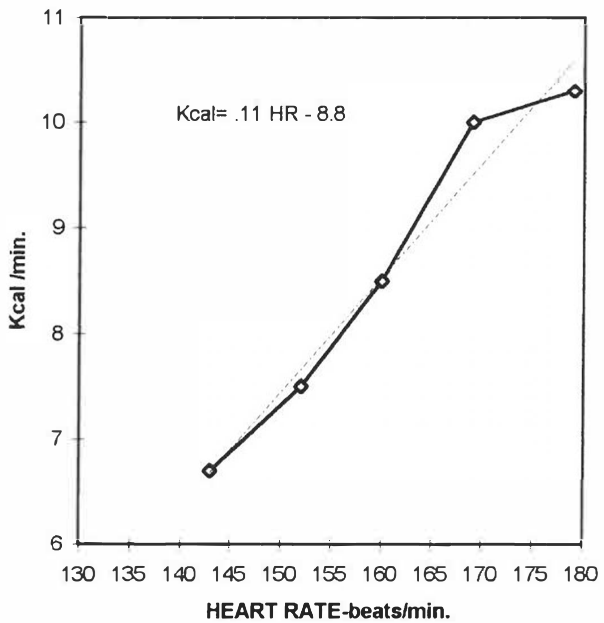

Fig.8. Relationship between heart rate and energy consumed during treadmill exercises

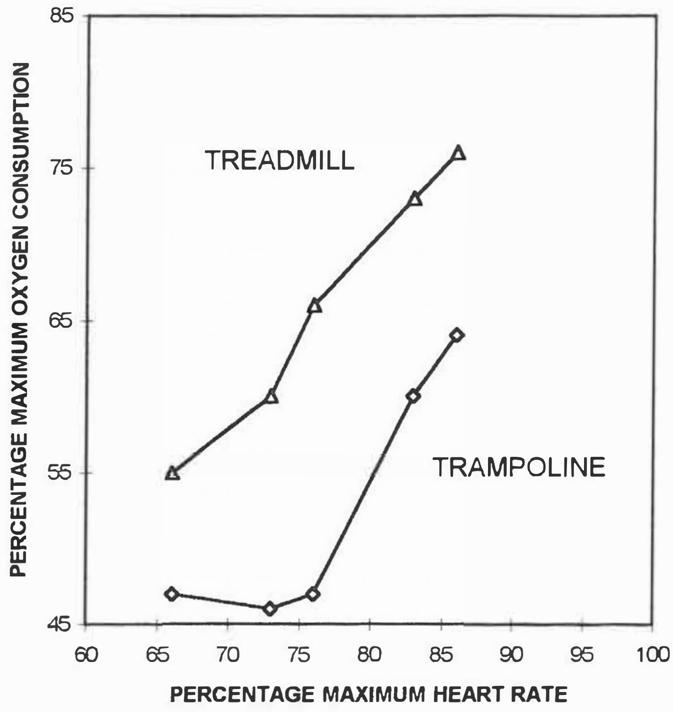

Fig.9 Comparison of percentage of maximum heart rate and percentage of maximum oxygen consumption between treadmill and trampoline exercises.

An examination of Fig.9 reveals that for increases in the percentage of maximum heart rate from 65 to 75% there was practically no increase in the percentage of maximum oxygen consumption for trampoline exercises. However, for treadmill exercises the linear relationship between percentage maximum heart rate and percentage maximum oxygen consumption is evident. This may be an important factor to consider when prescribing exercise intensity for weight loss programs using the mini-trampoline.

CHAPTER 5

DISCUSSION

Although the technique of using heart rate as a marker of exercise intensity and estimation of energy expenditure is practical. it may not always be accurate. The validity of the VO_2 /HR relationship has been investigated for general activities such as treadmill running but not for activities such as rebounding on a mini-trampoline.

Furthermore, it is generally accepted that an exercise heart rate of approximately 70% of maximum is required to result in an improvement in aerobic capacity. This is equivalent to about 50 to 55% of the maximum aerobic capacity. This intensity appears to be the minimal stimulus required to provide training improvements (McArdle et al.1991).

In the training studies by White (1980), Katch et al. (1981), Gerberich et al. (1983), Evans et al. (1984), and Tomassoni et al. (1985), we note that the subjects exercised on the trampoline for 30-40 min per session. To rebound, even at a self chosen pace as described by Katch (1981), for this duration, the subjects must have rebounded at between 100 to 160 steps per min. It has been our observation in this study that to rebound above 160 steps per min for more than 10 min was difficult for sedentary subjects. At a step frequency of between 100 to 160 steps per min and maintaining a "normal" comfortable rebound height the subjects could have reached and maintained a heart rate of 65-75% of maximum.

The first major finding of the current study was a non linear relationship between VO_2 and heart rate while exercising on a mini trampoline. This was not the case for treadmill exercise, which showed a linear relationship between the two variables. In our study when the subjects rebounded at increasing step frequency from 100 to 200 steps per min they reached a heart rate of 66 to 83% of the maximum heart rate obtained by a treadmill test. However, the oxygen consumption remained constant at about 1.5 *l* per min or 47% of maximum over the first three workloads. Although the heart rate response of 66 to 83% of maximum is certainly considered sufficient to improve aerobic capacity, the corresponding oxygen consumption of 47% of maximum is below the minimal stimulus required to provide training improvements. This has implications for setting the stepping frequency at above 160 for training purposes.

Factors other than the oxygen consumption by the working muscles that may effect the cardiovascular response to trampoline rebounding are anxiety, body position, the muscle groups exercised, whether the muscles are contracting isometrically or rythmically and the relative contribution of heart rate and stroke volume to cardiac output. Physical exercise is associated with an increase in cardiac output relative to the oxygen consumption. If oxygen consumption is directly related to cardiac output, we may postulate that during the initial stages of mini-trampoline exercises the cardiac output also remains constant despite increasing heart rate. Cardiac output is the product of the heart rate and stroke volume therefore if cardiac output remains constant but the heart rate has increased this would result in a commensurate reduction in stroke volume. In order for this to occur there must be some factor during trampoline exercises that effectively reduces the stroke volume.

The rhythmic muscle contractions of dynamic exercise increase the venous return and the intrathoracic and pulmonary capillary blood volumes (Dempsey, Gledhill, Reddan, et al. 1977). The increase in these central volumes increases the reserve volume, thus providing for an enhanced preload for the heart and hence an increased stroke volume. This, however, does not seem to be the case for trampoline exercises with an intensity level of between 100 to 160 steps per min. It is apparent that at this exercise intensity level trampoline exercise has the effect of reducing venous return. The cause of this apparent reduction in stroke volume is not elucidated by the current study.

The important practical implication of this study is that the monitoring of the heart rate response during trampoline jumping is a poor physiological marker of the exercise intensity. The study by Gerberich et al. (1990), showed an increase in heart rate as well as VO_2 when the stepping rates were increased from 105 to 205 steps per min. These authors also reported a plateau of the VO_2 during trampoline jogging between the heart-rate of 156 to 170 bpm. In contrast to this, the present study showed a substantial increase in VO_2 between the same range of heart rate (Fig. 1) although the testing procedure was almost identical. The reason for this disparity is not absolutely clear. However, some of the differences in the study between Gerberich et al. (1990) and the current study are:

1) In the study by Gerberich et al. (1990) only female subjects were tested.

2) In the current study the subjects were carefully monitored so that they maintained a leg lift of 15 cm above the rim of the trampoline at all times as opposed to maintaining a knee angle of 45 degrees. The importance of this is that with increasing cadence the leg lift tends to become reduced, hence, reducing the work output.
3) The subjects in the study by Gerberich et al. (1990) did not rest in between stages of increasing cadence as was the case in the current study.

Secondly, an inappropriate ventilation is evidenced by a high Ve / VO_2 ratio at low workloads on the trampoline. Previous studies have indicated that the perceived exertion is closely related to the individual's ventilation (Gerberich et al. 1990). These authors also concluded that the plateau of the VO_2 demonstrated during rebound jogging was perceived as increasing exertion which I believe may have resulted from the higher level of ventilation. I speculate that this may have resulted in a higher rate of perceived exertion than was metabolically apparent. However, this was not investigated in the current study. This has practical implications for exercise prescription in keeping with the first finding. The individual may tend to overestimate their level of exercise, resulting in an insufficient level of exercise for improvement in aerobic capacity or desired weight loss. Therefore, if one uses the heart rate response during trampoline exercises to predict oxygen consumption and hence the energy cost of rebounding, one would be grossly overestimating the energy cost of the exercise.

The third major finding is that the leg lift during rebounding is critical in the prescription of exercise intensity. Increasing the leg lift from 15 cm above the trampoline bed to 90 degrees of hip flexion resulted in significant increases in both oxygen consumption (Fig.2), and heart rate (Fig.3). Increasing the angle of the hips to 90 degrees while rebounding at 120 steps per min had the effect of increasing oxygen consumption by 40.8% and heart rate by 19.5%. Therefore, raising the height of the leg lift is advisable if wishing to increase exercise intensity.

White (1980), required his subjects to rebound at an exercise heart rate of 150 beats per minute. He reported a 12.8% loss of fat or a 12 kg loss of body weight and an increase in VO_{2max} of 10.3 % following a 10 week training period. The results of the present study indicated that when the subjects rebounded at a heart rate of 150 beats per min they utilised on an average, 1.5 l/min of oxygen which represented about 6.5 kcal per min of energy. At this rate of energy expenditure I would be inclined to agree with the calculations of Katch et al. (1981) who suggested that the weight loss experienced by the subjects in the study by White (1980) must have come from dieting or other activities and could not have resulted from rebounding alone. Hence monitoring heart rate may give an overestimation of the intensity of rebounding both for fitness training and weight reducing programmes.

In order to use the mini-trampoline effectively for fitness or weight loss programs the exercise intensity must be fully and exactly specified. From the present study it is apparent that exercising on the trampoline below 200 steps per min with the leg lift at 15 cm is not sufficient to elicit positive improvements in aerobic capacity. Hence, additional muscle groups have to be recruited while exercising on the trampoline in order to effectively stimulate the cardiorespiratory system. The present study has shown that by increasing the leg lift to 90 degrees of hip flexion while jogging at 120 steps per min has this effect. At this exercise intensity the subjects made greater use of their trunk and upper limb muscles in order to maintain their stepping frequency and leg lift height.

FUTURE STUDIES.

A major problem that occurs when comparing the results of different studies involving trampoline exercise is the absence of a standard exercise protocol. The intensity of the exercise including step height and frequency should be standardised. In order to increase the intensity of rebounding Bishop et al. 1986, suggested the use of hand held weights. They demonstrated that pumping hand held weights at different heights while rebounding will increase the oxygen requirements from 26 to 60 %. There are some indications, however, that this procedure disproportionately increases systolic blood pressure, perhaps due to the elevated intramuscular tension with gripping the weights. This could restrict the use of hand held weights for persons with existing hypertension or coronary heart disease. Further investigation of the metabolic requirements of mini-trampoline exercise with hand held weights is required.

It has become obvious during the study that trampoline exercises in its various forms vary greatly. Treadmill exercise provides for horizontal motion and trampoline exercises, vertical displacement. This factor needs to be considered when comparing the results from these two different types of exercise. A more specific exercise type eg. vertical stepping on a stepper which provides vertical motion and also an amount of auto-assistance may be a more appropriate type of exercise to compare with trampoline exercise.

CONCLUSION

From the findings of the present study it is evident that increasing stepping rates above 160 per min or increasing the leg lift during rebounding has the potential to

elicit positive cardiovascular responses. However, it has been shown that the use of heart rate monitoring during trampoline exercises gives a false perception of exercise intensity, and should not be used as a physiological marker of exercise intensity. Several authors have used the heart rate results obtained by a treadmill test as an indicator of the intensity of exercise during rebounding. From the present study it has become evident that exercising at the same heart rate on both the treadmill and the trampoline elicits varying responses in terms of oxygen consumption, ventilation and energy consumption. Although we support the use of the mini-trampoline as an exercising tool, the use of heart rate as a physiological marker to monitor the intensity of exercising for fitness or weight loss programs is not advisable.

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CONSENT FORM

TO ESTABLISH AN EXERCISE PRESCRIPTION FOR TRAMPOLINE JUMPING USING THE PHYSIOLOGICAL PARAMETER VIZ. HEART RATE.

I ...., freely and voluntarily consent to participate in a research programme under the direction of ANWAR KHAN (investigator) and Professor M.Mars (supervisor) , to be conducted in the Exercise laboratory of the Physiology department of the University of Natal.
A through description of the procedures has been explained and I understand that the risks involved may include muscle soreness or falling off the trampoline or treadmill. I fully understand that a trained medical person will be present during the test.
I understand that I may withdraw my consent and discontinue participation in this research at any time with out prejudice to me.
I authorise ANWAR KHAN, and the department of Physiology to keep, preserve, use and dispose of the findings from this research with the provision that my name will not be associated with any of the results.
I have been given the rights to ask any questions concerning the procedures to be used during this research. Questions have been answered to my satisfaction . I have read and understand the contents of this form and have received a copy.

....	....	....
WITNESS	DATE	PARTICIPANT

I, ANWAR KHAN, have explained and defined in detail the research procedure to which the subject has consented to participate .A copy of the procedure explained to the participant is attached.

....	....
SIGNATURE	DATE

PROCEDURE OF STUDY EXPLAINED TO PARTICIPANT
_A. EXERCISE ON TREADMILL: A resting heart rate will be taken. You will then be connected to a gas analyser via a mouth piece.This means that during the exercise you will breathe through the mouth piece which is connected to the gas analyser.You will also wear a nose clip to prevent the escape of air through the nose.You will then run on the treadmill at a steadily increasing rate for a period of between ten to fifteen minutes.Thereafter you will be allowed to rest before the next exercise begins on the trampoline.
B. EXERCISE ON TRAMPOLINE: A resting heart rate will be taken.Once again you will be connected to the gas analyser as before.You will then jump on a trampoline with alternate feet striking the trampoline to the beat of a metronome which will be used to increase the rate of jumping. The exercise will stop once you have reached the maximum heart rate you attained during the exercise on the treadmill. You will then be disconnected from the breathing apparatus and your participation in this study will be over.

HEART RATE vs OXYGEN CONSUMPTION DURING MINI-TRAMPOLINE EXERCISE

Name: ....

Age: ....

Subject #: ....

Pred HRmax: ....

Height: ....

Weight: ....

	Tick when completed
Familiarisation on treadmill	......
Informed consent form	......
Medical history	......

Testing on MT

		HRmean	VO2	Tick
Warm-up:	3 mins familiarisation	......	......	......
Rest:	2 mins		......	......
100 steps/min	3 mins	......	......	......
Rest	1 min		......	......
120 steps/min	3 mins	......	......	......
Rest	1 min		......	......
160 steps/min	3 mins	......	......	......
Rest	1 min		......	......
200 steps.min	3 mins	......	......	......
Rest	5 mins		......	......
120/Knees 90°	3 mins	......	......	......
Rest			......	......
Download HR monitor			......	......

Testing on Treadmill

		Speed/slope	VO2	Tick
Warm-up	3 mins	......	......	......
Rest	2 mins		......	......
HR=	3 mins	......	......	......
Rest	1 min		......	......
HR=	3 mins	......	......	......
Rest	1 min		......	......
HR=	3 mins	......	......	......
Rest	1 min		......	......
HR=	3 mins	......	......	......
Rest	5 mins		......	......
HR=	3 mins	......	......	......
Rest				......
Download HR monitor				......
Print and label VO2 report				......

CALORIC VALUE OF A LITER OF OXYGEN AT VARIOUS NONPROTEIN RESPIRATORY EXCHANGE RATIOS *

rotein iratory nge Ratio	Calories per Liter Oxygen Consumed	Calories Derived From Carbohydrate Percent	Fat Percent
0.70	4.686	0	100 0
0.71	4.690	1.10	98.9
0.72	4.702	4.76	95.2
0.73	4.714	8.40	91.6
0.74	4.727	12.0	88.0
0.75	4.739	15.6	84.4
0.76	4.751	19.2	80.8
0.77	4.764	22.8	77.2
0.78	4.776	26.3	73.7
0.79	4.788	29.9	70.1
0.80	4.801	33.4	66.6
0.81	4.813	36.9	63.1
0.82	4.825	40.3	59.7
0.83	4.838	43.8	56.2
0.84	4.850	47.2	52.8
0.85	4.862	50.7	49.3
0.86	4.875	54.1	45.9
0.87	4.887	57.5	42.5
0.88	4.899	60.8	39.2
0.89	4.911	64.2	35.8
0.90	4.924	67.5	32.5
0.91	4.936	70.8	29.2
0.92	4.948	74.1	25.9
0.93	4.961	77.4	22.6
0.94	4.973	80.7	19.3
0.95	4.985	84.0	16.0
0.96	4.998	87.2	12.8
0.97	5.010	90.4	9.58
0.98	5.022	93.6	6.37
0.99	5.035	96.8	3.18
1.00	5.047	100.0	0

er Zuntz and Schumberg, in Lusk, G., <u>The Elements of the Science of rition</u> (4th ed.). Philadelphia: W. B. Saunders, 1928, p. 65.