ABSTRACT:

Background:

When prescribing exercise training, percentage of heart rate maximum (HR_{max}) is often used to guide exercise intensity. To be able to use heart rate (HR) as a measure of exercise intensity, it is important to know what an individual's HR_{max} is. Although several equations have been established to calculate an individual's HR, there is a large inter-individual variation in HR_{max}, making such estimations less valid. In exercise studies, a maximum effort cardiopulmonary exercise test (CPX) is often undertaken at baseline to establish the maximum work load or maximum oxygen uptake of the subjects. It is a common practice to add some beats (usually 5-6) to the highest HR obtained during a CPX to estimate the HR_{max} . There is, however, a lack of data providing evidence for such an addition. Our aim was therefore to investigate how well a maximum HR obtained during a CPX would predict the maximum HR obtained during a test designed to reach HR_{max}.

Methods:

We included 68 participants (31 women/37 men, age 43±19, $VO2_{peak}$. 50,6 ±6,9). All subjects underwent two different tests, on separate days; a CPX using a individualized ramp protocol and a maximum effort interval test designed to reach HR_{max}. HRmax prediction models based on maximum HR reached at the CPX test were derived from multiple linear regression analysis. We also included other independent variables that can affect the HR_{max}; age, gender, fitness level, height and weight.

Results:

The maximum HR reached at the CPX test ($HrVO_2$) explained 90,2% of the HR_{max} at the interval test. The regression equation obtained in this study, $HR_{max} = HrVO_2 \times 0{,}954 + 11{,}391$, includes only $HrVO_2$ as a variable. The other independent variables gave only minimal changes in R^2 and were thus excluded from the equation.

Conclusion:

The maximum HR obtained in a CPX test to exhaustion provides a fairly accurate estimate of the HR_{max}.

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Trondheim, June 2016

Sara Elisabeth Sørås and Bård Even Relling

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INTRODUCTION:

Studies have found that exercise capacity can be used to predict early death in individuals, and increased exercise capacity is associated with longevity (1, 2). Heart rate (HR) is an often used tool to prescribe exercise intensity, expressed as percentage performance of the maximum heart rate (HR_{max}) (3). Furthermore, HR_{max} measurements are used in clinical rehabilitation and disease prevention programs to assess the response of the heart to exercise (4).

A common equation used for predicting the HR_{max} of an individual is 220 minus age (4). The origin of the formula HR_{max}=220-age dates back to 1938 from the researcher Sid Robins, who were the first to develop a formula that predicts HR_{max}. Later studies have proven that this equation has little application in exercise physiology and related fields (3). The greatest problem with this formula and with formulas that derives from the original one, is that the prediction in errors in HR_{max} needs to be very low, often less than 3 beats per minute (3). In most cases the difference was a lot more than 3 beats. The equation has a large standard error of estimate (3). Although such formulas might be useful for finding an average HR_{max} for a group of participants, they are limited in their ability to predict an individual HR_{max} correctly due to the high standard deviation seen in HR_{max} (5).

However, several studies have found that the estimate of HR_{max} based on such equations is not precisely predicting the true HR_{max} (3,6). It has been shown to be a large inter-individual variation (6), but a low intra-individual variation (7). Other studies (8-10) have suggested equations to estimate the HR_{max} based on age, but such equations have been found to be unreliable (3). As far as the authors know, there exists no 'gold standard' protocol to determine HR_{max}. To reliably establish participants' HR_{max}, it is common to do a test with repeated near-maximum workloads before a final interval with maximum effort, leading to a higher HR at the last interval (11). It has, however, been suggested, that an individual will reach HR_{max} if two subsequent maximum exercise efforts of 3-4 minutes are undertaken (11).

Maximum oxygen uptake (VO_{2max}) is considered the best measure of cardiorespiratory fitness and an important determinant of endurance performance (12). VO_{2max} is the highest amount of oxygen the body can take up and utilize during severe exercise (13). High intensity Interval Training (HIT) is an effective exercise regime for increasing the fitness level of both healthy participants and cardiac patients (14-17). A commonly used HIT model is the 4 x 4 minutes HIT with intensity of 85-95% of individual HR_{max} during the intervals. To be able to use HR as a tool to guide exercise intensity during traditional endurance exercise as well as HIT, it is important to know the true HR_{max} of the participants. In clinical studies, it is common to use the highest HR value of a cardiopulmonary exercise test (CPX) to volitional fatigue and then add 5-6 beats to establish what is thought to be the participants HR_{max}. On some occasions however, participants are able to exercise with a higher HR than what was reached at the CPX test, indicating that a true HR_{max} could not be established based on this test.

The aim of this study was to assess the association between HR_{max} found during a standard CPX test to exhaustion and the HR_{max} found during a test with repeated high workloads as intervals designed to measure the HR_{max}. Our research question was: How well does a HR_{max} found during CPX testing reflect HR_{max} found during HR_{max} testing? Based on our experience (11), we hypothesized that the HR_{max} found during repeated interval testing would be 5-6 beats higher than the HR_{max} found during CPX test.

METHOD:

Participants:

As an inclusion criterion the participants had to be able to walk or run on a treadmill with enough intensity to exhaust them. Exclusion criteria included: pregnancy, known cardiac or pulmonary diseases, taking medication that affects heart rate, and any kind of physical injuries that restricts performance. We aimed at including an equal proportion of low and high fitness levels, based on participants´ self reported level of physical activity (attachment 1, questionnaire).

The participants were recruited through word-of-mouth and advertisements at public places; such as the university campus, student gyms, university collages, different wards at the hospital, libraries, stores and at the webpage for volunteering at CERG (http://www.ntnu.no/cerg/frivillige).

Participants who reported doing regular endurance training twice weekly or more were categorized as high fitness and participants who reported less, as low fitness. The intention of this division was to ensure that a wide range of the population was presented in the sample, and not only participants from one of these two groups. To make certain that they were included in the right category, each participant were once again divided into either high or low fitness groups after completed CPX test; the achieved VO_2max, gender and age were used to determine their fitness status (18). Participants having a VO_2max below the mean value for their group, determined by age and gender, were categorized as low fitness (18).

Participants between the age of 20 and 69 was recruited for the study to ensure that a wide age range was represented in the sample. Regarding gender, both men and women were included equally.

Measurements:

Each participant came to the laboratory twice to do two different test protocols, in random order, separated by two days or more. The participants were asked to avoid any high intensity endurance activity for minimum 48 hours before taking the test. Participants agreed to be well rested and hydrated, and to have had a meal 2-3 hours before the test.

Cardiopulmonary Exercise Test

We used an individualized ramp protocol treadmill test to volitional exhaustion (19). The test started with a 10 minutes warm-up at light to moderate intensity. We set the inclination of the treadmill (Woodway) to 5% or more and increased the speed by 0,5-1 km/h per minute. The test was continued until the participants were exhausted and could not perform any further. We registered the highest HR reached during this test by use of HR belts (Polar RCX3 FCCID:INWX1, CE0537). The VO_2max was measured using Jaeger Oxycon Pro, Type V (Viasys Healthcare GmbH). To establish the VO_2max (in ml/kg/min) for each participant, we used the three highest adjacent measurements found during the CPX test and calculated the mean value. To ensure that the participants achieved maximal exertion, each participants had to meet three out of the four following criteria: 1) a plateau in $\dot{V}o_2$ with increasing exercise intensity (<100 ml) (20); 2) a respiratory exchange ratio of at least 1.10 (21); 3) a maximal respiratory rate of minimum 35 breaths/min (22); 4) a rating of perceived exertion of at least 17 units on the BORG scale (23).

Heart Rate Maximum Test

The HR_{max} test were designed to make the participants reach their HR_{max} by making them exercise at near-maximum effort in three intervals (Table 1). The test started after 15 minutes of warm-up with a 50-65% of HR_{max}. The participants then did one four minute interval of approximately 90% of their estimated HR_{max}. The estimation of their 90% HR_{max} was based on either previous result of CPX-test, or self-reported HR_{max}. After a two-minute active pause at moderate intensity, the participants did another four minute interval at 90% HR_{max}. After two more minutes of moderate intensity, the participants started the last interval with two minutes of 90% HR_{max} followed by an increase of speed or incline for every 30 second until volitional exhaustion. The highest HR during the test was recorded. (Polar RCX3 FCCID:INWX1, CE0537).

Table 1: HR_{max}***-interval test illustration***

	Time:	**Intensity:**	**HR:**
Warm up:	15 min	50-65% of HR_{max}	
1st interval:	4 min	90% of HR_{max}	
Pause:	2 min	50-65% of HR_{max}	
2nd interval:	4 min	90% of HR_{max}	
Pause:	2 min	50-65% of HR_{max}	
3rd interval: • **1st increase** • **2nd increase** • **3rd increase** • **4th increase**	2 min • 30 sec • 30 sec • 30 sec • 30 sec	90% HR_{max} • 0,5-1,0 km/h • 0,5-1,0 km/h • 0,5-1,0 km/h • 0,5-1,0 km/h	Registering the highest HR reached during the increases, before the HR declines.
Cool-down:	10 min	Individual	

Statistics:

The data in this study were analyzed by using SPSS version 23, release 23.0.0.0. Multiple linear regression was used to establish how well the HR_{max} reached during a standard CPX test was associated with the HR_{max} reached during the test that was designed to measure the “true” HR_{max}. A p-value of < 0.05 was considered to be statistically significant. In addition to HrVO2, other independent variables such as age, weight, height, gender and fitness were also included. Several multiple linear regressions with different independent variables were executed to evaluate to which degree the different independent variables are associated with the HR_{max} measured during the interval test (HrI). The two regressions with the best correlations were presented as Model A and Model B. The association observed in these two models were compared to estimate which factors influence the HrI the most. The R-squared value (R^2) was used to indicate how much the independent variables explain the variance of the dependent variable, while the adjusted R^2 was used to predict what the probability is that the changes of HrI is due to changes of the independent variables.

In statistical analysis based on linear regression analysis, several assumptions must be true before it is possible to draw any conclusions. For example, the independent variables have to be categorical or quantitative. There has to be no external variables that correlate with the independent variables. Independent errors comprise that the residuals from two observations do not correlate with each other (i.e., that the errors are independent of each other). This assumption was tested with the Durbin-Watson-test. The value of the correlation between two variables can vary between 0 and 4, where 2 means no correlation between the two residual values. The independent variables also have to differ in value and not have a perfect linear relationship between each other. The mean values of the dependent variable (Y) for each of the independent variables lies along a straight line, which means that the relationship between the two are linear. According to the assumption for linear regression, it is assumed that each result (Y) is independent from the next result, and that they are independent from each other. Another assumption that needs to be tested is multicollinearity, which is when two or more independent variables have high correlation with each other. To detect this phenomenon, the correlation coefficients and the tolerance value were observed. Tolerance is the amount of the variation of one independent variable that is not in relation to the remaining independent variables. The value of tolerance should be higher than 0,1. In addition, there should not be any significant outliers (24)

RESULT:

This study included 68 participants, 31 females (45,6 %) and 37 males (54,4%). All of them completed both the standard CPX test and the HR_{max} test with intervals, satisfying at least three out of four criterions for a successful CPX test. Table 2 outlines the characteristics of the participants. 66,2 % of participants were characterized as high fit. The age of the participants ranged from 24 to 62, with the majority (64,7%) of them under 40 years.

Table 2. Characteristics of the participants.

Characteristics	**Total (n=68)**
Age (years)	36,2 ± 10,5
Range	43 ± 19
Height (cm)	176,1 ± 9,8
Weight (kg)	75,4 ± 13,6
Gender (n(%))	
Male	37 (54,4%)
Female	31 (45,6%)
Fitness (n(%))	
High	45 (66,2%)
Low	23 (33,8%)
Cardiopulmonary exercise test variables	
VO_2max (ml/kg/min)	50,6 ± 6,9
RER (VCO_2/VO_2)	1,12 ± 0,1
Respiratory rate (/min)	54,8 ± 7,8
BORG	18,0 ± 1,0
HrVO_2 (bpm)	186,3 ± 10,9
HrI (bpm)	189,0 ± 11

Values are mean ± standard deviations, if not otherwise noted. VO_2max = maximal oxygen uptake; RER = respiratory exchange ratio; BORG = rating of perceived exertion; HrVO_2 = maximal heart rate reached at CPX-test; HrI = maximal heart rate reached at maximum heart rate interval test.

Prediction of heart rate maximum:

Table 3. Multiple regression analysis for predicting maximal heart rate.

	R^2	Adjusted R^2	Durbin-Watson
$HrVO_2$	0,902	0,900	2,355
$HrVO_2$, Age	0,903	0,900	3,364
$HrVO_2$, Age, Gender	0,903	0,899	2,373
$HrVO_2$, Age, Gender, Fitness	0,905	0,899	2,305
$HrVO_2$, Age, Gender, Fitness, Height	0,906	0,898	2,299
$HrVO_2$, Age, Gender, Fitness, Height, Weight	0,906	0,896	2,298

R^2*: coefficient of determination;* $HrVO_2$ *(beats/min), Age (yr.), Gender (male/female), Fitness(high/low), Height (cm), Weight (kg).*

Table 3 shows $HrVO_2$ being the paramount contributing variable accounting for most of the variance in the prediction model, with a R^2 of 0,902. The independent variable $HrVO_2$ explains 90,2 % of the variability in the dependent variable HrI. Adding the other four variables gave essentially the same result as using only $HrVO_2$. Adjusted R^2 declined with increasing number of independent variables.

Table 4 presents a multiple linear regression of two models, Model A and Model B. In model A, HrI is related to one independent variable, the HR_{max} measured with the CPX test (HrVO2). In model B, HrI is related to several independent variables; HrVO2, age, weight, height, gender and fitness.

Table 4. Multiple linear regression coefficients and analysis for predicting maximal heart rate

Model		Unstandardized coefficients B	Standardized coefficients Beta	95% confidens interval for B		Sig.	Collinearity statistics		Adjusted R^2	R^2	Durbin-Watson
				Lower	Upper		Tolerance	VIF			
A	$HrVO_2$	0,954	0,950	0,876	1,031	0	1	1	0,900	0,902	2,355
	Constant	11,391		-3,038	25,819	0,120					2,298
B	$HrVO_2$	0,976	0,969	0,882	1,064	0	0,749	1,335	0,896	0,906	
	Weight	-0,003	-0,004	-0,135	0,130	0,966	0,228	4,381			
	Age	0,039	0,037	-0,057	0,135	0,420	0,738	1,355			
	Height	-0,037	-0,033	-0,246	0,173	0,782	0,175	5,720			
	Gender	1,22	0,056	-2,160	4,600	0,473	0,259	3,866			
	Fitness	1,215	0,045	-1,021	3,451	0,281	0,897	1,115			
	Constant	11,372		-27,382	50,127	0,560					

R2: coefficient of determination; $HrVO_2$ (beats/min), Age (yr.), Gender (male/female), Fitness(high/low), Height (cm), Weight (kg).

Assessing the coefficients in model B and their corresponding p-values indicates that $HrVO_2$ is the only predictive variable which is statistically significant with a p-value <0.05 (sig.=0, table 4). This is applicable for both model A and B. Because the other predictor-variables all have p-values > 0.05, we can assume that their correlation with the dependent variable (HrI) is not statistically significant.

The adjusted R^2 in model A is 0,900 and for B 0,896. Adjusted R^2 predicts what the probability of the changes of HrI are, which is due to the changes of the independent variables. It corrects for the positive bias and shows the value expected in the population. R^2 in model A is 90.2% with adjusted R^2 being 90.0%, while R^2 in model B is 90.6% with adjusted R^2 being 89.6%, which means that the predictors affect the dependent variable to a great extent, and more in model A than in model B.

The value of the Durbin-Watson calculation for regression model A was 2,355 and 2,298 for model B (Table 4).

The unstandardized coefficients represent the change in the dependent variable for a one unit change in the independent variable, provided that the other variables are held constant. Weight and height were the only variables that give a negative influence on HR_{max} with increasing value. The coefficients for weight and height were -0,003 and -0,037, respectively (Table 4). Including weight and height into the regression model gave only minimal changes in R^2 and were thus excluded from the final equation models.

With these coefficients, regression equations can be presented in the following form:

Model A:

$$HR_{max} = HrVO_2 \times 0{,}954 + 11{,}391$$

Model B:

$$HR_{max} = (HrVO_2 \times 0{,}976) + (Gender \times 1{,}22) + (Fitness \times 1{,}215) + (Age \times 0{,}039) + 11{,}372$$

The 95% coefficient interval for the variable $HrVO_2$ is in model A 0,876 - 1,031 and for model B 0,822 - 1,064. Table 4 shows that this is the only variable with a coefficient value that does not cross zero in the 95% interval.

Normality:

The histogram (attachment 3) gives the impression of a normal distribution of the standardized residuals. The mean value should be close to 0 and the standard deviation close to 1. These criteria are met in the dataset. In the Normal Q-Q Plot (attachment 2) the residuals are aligned approximately along the diagonal line, close enough to indicate that the residuals are adequate for analysis. The assumption for normality is fulfilled.

Scatterplot HrInterval / $HrVO_2$:

The residuals form a band along the predicted line and it is not horizontal (attachment 4), so one can assume that the relationship between dependent variable and the independent are likely to be linear.

Checking for unusual points:

To identify outliers residuals greater than ± 3 standard deviations in the variable studentized deleted residual, SDR1, were checked for. The range in our data set is 2,809 to -2,563, so no outliers were found by analysing the residuals. To identify leverage points, the maximum accepted leverage value was set to 0,2. The highest value were 0,176. To determine whether there were any cases of particular influence, the values of Cooks Distance were inspected. The rule of thumb is to investigate cases with values above 1. Our highest Cooks Distance were 0,285.

Tolerance:

Assessing the collinearity statistics, table 4 outlines that all the values of Tolerance for both model A and B are above 0,1, ranging from 0,175 to 1.

DISCUSSION:

The main finding in the present study was a statistical significant correlation between HR_{max} measured in the two tests, interval test and CPX test ($p<0.05$). To estimate the true HR_{max} by measuring $HrVO_2$, the $HrVO_2$ value is multiplied with 0,954 and 11,391 beats are added (model A). The mean difference between the result of HR_{max} in the two tests is 2,7 bpm (seen in table 2). This indicates that adding 5-6 beats to the HR_{max} found in CPX test may be to much.

$HrVO_2$ accounts for about 90% of the variance in HrI. Adding other independent variables in the regression did not contribute to considerable changes in prediction. In clinical practise this means that the influence of age, weight, height, gender and fitness on HrI are likely minimal. Also the coefficient interval for variable $HrVO_2$ emphasizes this point; being the only coefficient value that does not cross zero in the 95% interval, makes it the only variable with a statistical significant slope coefficient. In practice this means that to estimate the HR_{max} in model A, it is 95% likely that it is necessary to multiply the HR_{max} found in the CPX test with a number between 0.876 and 1.031, and to add 11,4 to this number. The other independent variables, on the other hand, are not statistically significant and the correlation they have with the dependent variable is unimportant.

Since the unstandardized coefficient of weight and height constituted such small differences, those values were not included in this analysis. Increasing values of these variables had minimal effect on the HR_{max}.

This study aimed to satisfy the assumptions for multiple linear regression analysis by using variables that are categorical, like gender and fitness level, or continuous, like $HrVO_2$, age, weight, height. There were also no external variables that correlated with the independent variables, and therefore support this assumption. Furthermore, the Durbin-Watson- value was 2,355 for model A and 2,298 for model B) hence satisfying. These values are both close to 2,0 and gives the impression that the residuals are not dependent of each other. Additionally, the assumption about the collinearity does not seem to be violated in this data set, because the correlation between the independent variables are too small to affect their individual influence on the dependent variable, with a value of tolerance > 0.1.

Generalizability of the results:

More than half of the participants had above average VO_{2max}. By actively recruiting participants that do not do regular endurance exercise, or who has low fitness according to the HUNT study about fitness level (25), the risk of only measuring high fitness participants was reduced. However, our results showed that those with higher fitness levels more readily joined the study than those with lower fitness levels. The consequence might be that the result of the study is not valid to the same extent for the general population.

Another factor that might make the result only valid for one part of the population is the lack of participants that represent a wide age range. Young participants showed higher interest in participation, and it was particularly challenging to include participants from the oldest age group without breaking the exclusion criteria related to heart medication. The participants did not use heart medication and were free of known diseases. This might limit the generalizability of the result to the general population.

Strengths:

This study included a relatively large number of participants with a wide range of age (24 - 62 yrs) and VO_{2max}-range. The fact that the study has tested the necessary assumptions and that they all were satisfied, strengthens this study and implies that the result was sound.

Limitations:

Several factors might influence the participants' performance, and further affect the measures and give a false result of HR_{max} in the two tests. All the participants were asked to avoid high intensity endurance training more than 48 hours before the tests. However, it is uncertain whether they were adequately rested at both tests, and this might have influenced the results.

The degree of hydration affects the physical performance in many ways. Adequate drinking during and before exercise increases the participant's overall physical performance; hydration helps to attenuate the reduction in blood volume, cardiac output and muscle-blood flow. Drinking sufficient volumes of fluid before and during physical activity to minimize dehydration is arguably the simplest and most efficient means of sustaining physiological function and improving physical performance (14). Many of the participants joined the tests after a long day's work and might not have been well hydrated before starting the test. If they were well hydrated before only one of the tests, they would, according to Murray et al., perform better than if they were poorly hydrated. Lack of hydration before the HR-interval test will then result in a lower HR_{max} than the HR_{max} measured with the CPX-test if they were better hydrated at that test (26). Because of this, the participants may not have performed as well as their potentials at both of the tests.

Comparison with other studies:

As mentioned earlier, it is common to use the highest HR measured on a cardiopulmonary exercise test (CPX) to volitional fatigue and then add 5-6 beats to establish what is thought to be the participant's maximal HR. This estimation is often inaccurate, but still used both in clinic and in endurance sport settings. Compared to other studies, which often focus on finding the maximal heart rate with age as a variable, this study sought to look at the accuracy of adding 5-6 beats to HR_{max} found during CPX test. To the best of the authors knowledge, this has never been done before. This study shows that adding up to 6 beats may give a false maximal heart rate, which can give clinical implications. In physical exercise intervention programs they often adjust the intensity based on maximal heart rate, and as a result the target heart rate can become too high. Adding 5-6 beats to the maximal heart rate found in a CPX test is still considered a better estimation compared to frequently used age-equation.

Young well trained subjects are more likely to come close to the maximal heart rate during a CPX test than older subjects. This study had a 64,7% majority of participants under the age of 40. It might have led to a closer fit between the two test compared to a study with a greater amount of participants and a wider range of age.

The equation found in this study will acquire additional information from a CPX test, and may therefore not be suited for the general population. At the same time, the incorporation of this CPX test in the study strengthens the estimation made. By testing the participants with the CPX test prior to the interval test, a peak heart rate near the maximal heart rate of each individual was established. This makes it possible to predict in what range one can expect to find the true HR_{max} and minimizes the calculating errors of the individual difference.

CONCLUSION:

In conclusion, this study suggests to estimate the maximal heart rate by using the equation $HR_{max} = HrVO_2 \times 0{,}954 + 11{,}391$. The equation is based on the main finding of this study; the strong statistical significant correlation between HR_{max} measured in the interval test and CPX test. Due to the low significant correlation between the HR_{max} and the remaining independent variables, they are not included in this equation. Adding 5-6 beats to the maximal heart rate found during a CPX test is in this study shown to be excessive. To increase the generalizability of the result, it is suggested to aim for a greater degree of participants with a higher age and a lower VO2-max-level, in future studies.

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APPENDIX:

Attachment 1, Questionnaire:

Initials ☐☐☐☐ ID number ☐☐☐

QUESTIONNAIRE FOR PARTICIPANTS IN THE MAXPULS STUDY

In our study we are going measure the maximal heart rate on several subjects. This questionnaire will help us create a correct profile of each participant. We appreciate if you fill out this scheme as accurate as possible, and bring it with you on the first day of testing. If you have any questions, please contact us on email or telephone. You will find the contact information at the bottom of the scheme.

Date of today : ☐☐·☐☐·☐☐☐☐

PLEAS WRITE USING BLOCK LETTERS:

NAME:____

ADDRESS: ______________________________________

POSTAL CODE / CITY:________________________________

TELEPHONE NUMBER: ________________________________

E-MAIL ADDRESS: __________________________________

1

Initials ☐☐☐☐ ID number ☐☐☐

1) Gender ☐ Female ☐ Male

2) Age ☐☐ years

3) Have you been doing regular cardiopulmonary exercise training the last six months?

☐ Yes

☐ No *(move on to question 7)*

4) If yes, how many days a week?

☐ 1 day

☐ 2 days

☐ 3 days

☐ 4 days

☐ 5 days or more

5) Duration of each training session

☐ 0-15 min ☐ 16-30 min ☐ 31-45 min ☐ 46-60 min ☐ >60 min

6) The usual level of intensity

☐ Low. Without getting sweaty or out of breath

☐ Moderate. Mild sweating and sense of breathlessness

☐ Hard. Sweaty and heavy breathing (exhausting)

7) Do you smoke or use snuff(snus)?

2

Initials ☐☐☐☐ ID number ☐☐☐

☐ Yes, approximately ☐☐ cigarettes per day

☐ Yes, approximately ☐☐ snuffs(snus) per day

☐ No

8) Have you got asthma/allergy ? *(If no, move on to question 10)*

☐ Yes. Do you take medication for the asthma/allergy? ☐ Yes ☐ No

☐ No

9) Does the asthma/allergy limit your performance ?

☐ Yes

☐ No

10) Do you take any medication?

☐ Yes. What kind of medication?..

☐ No

11) Do you have any other injuries or diseases that may limit your performance ?

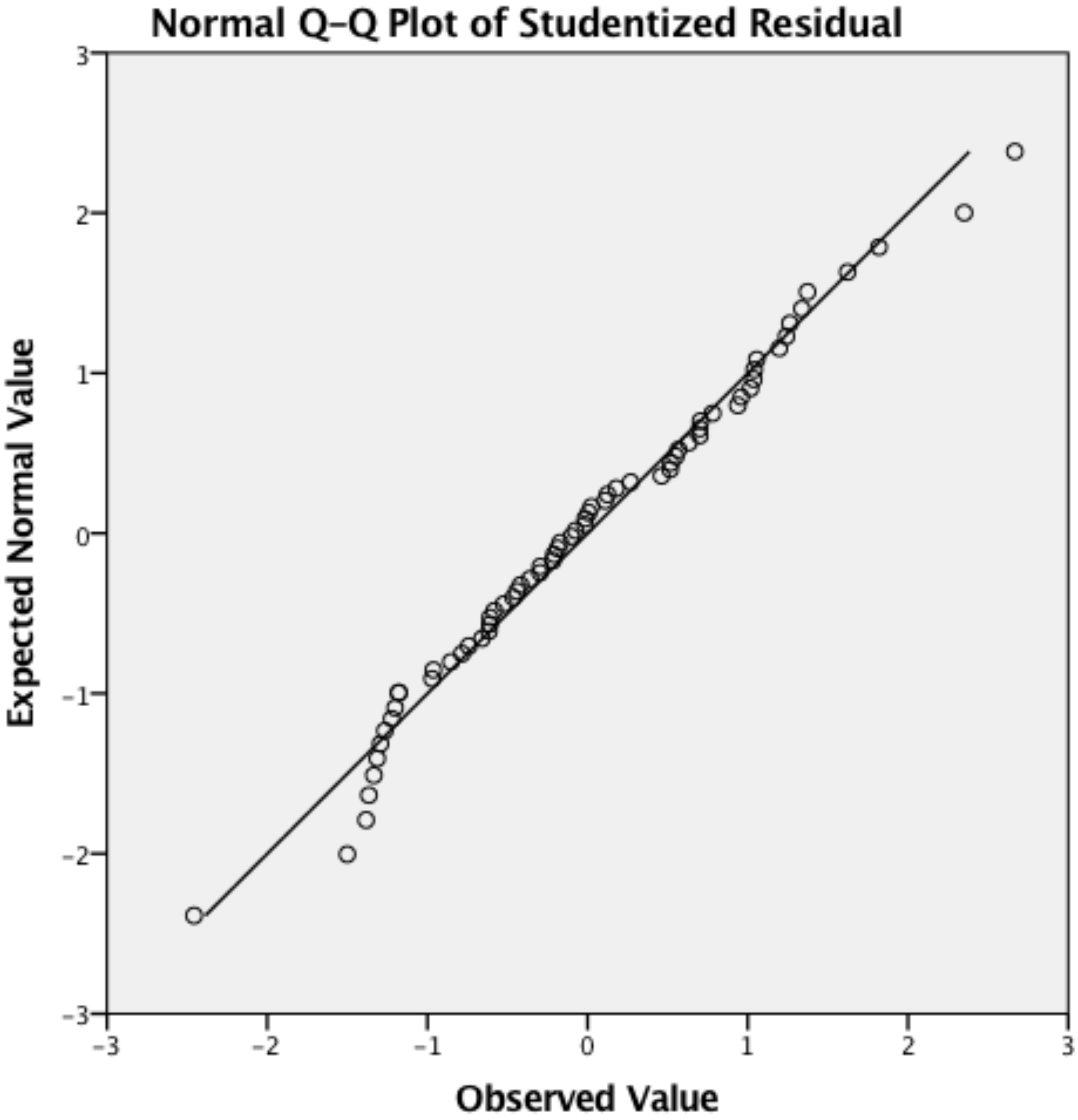
☐ Yes. What kind of injury/disease?..

☐ No

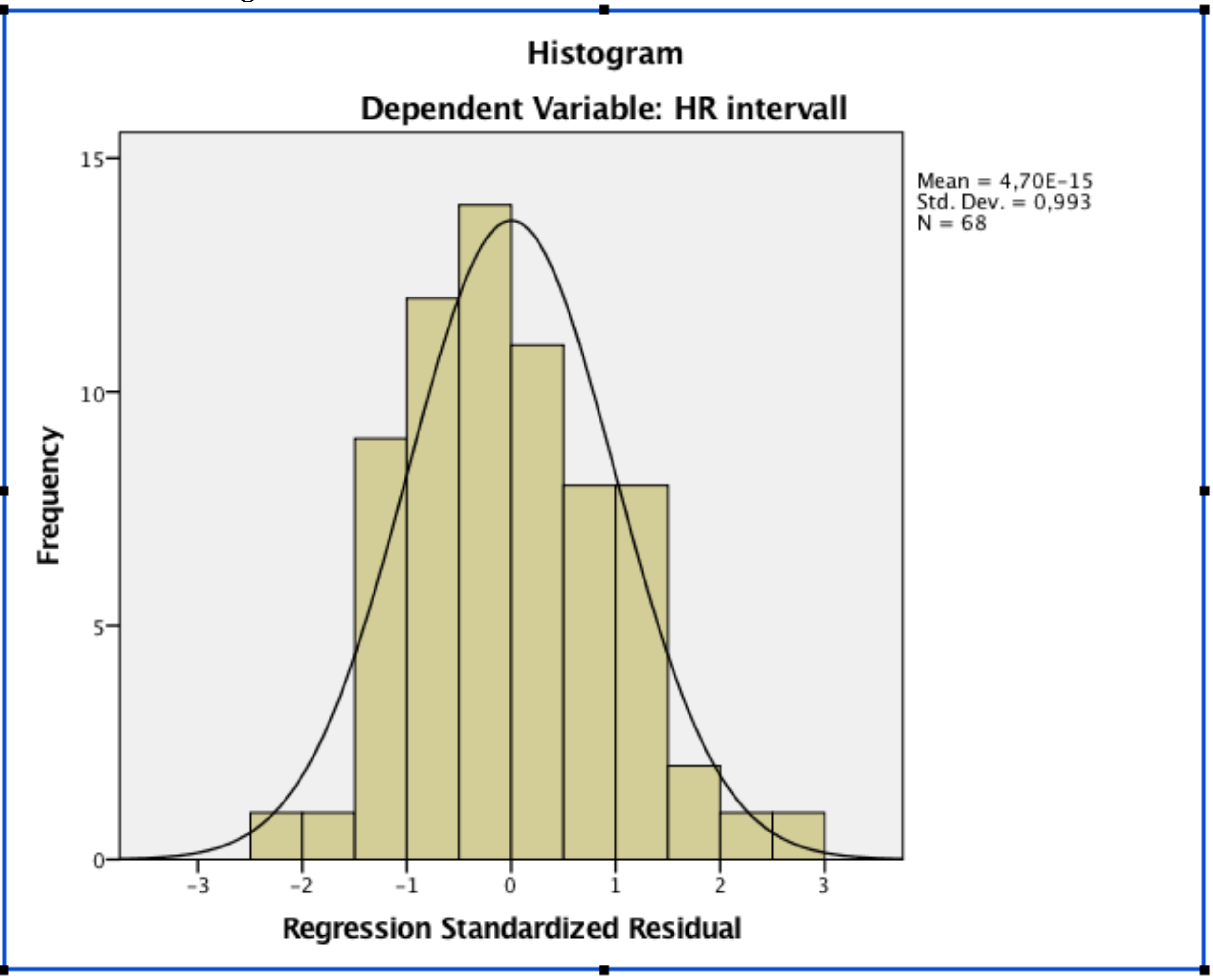
Thank you.

Sara Elisabeth Sørås (telephone number: 91142256, email: saraesr@gmail.com)
Bård Even Relling (telephone number: 45217736, email: bardeven@stud.ntnu.no).

Attachment 2, Q-Q Plot:



Attachment 3, Histogram:



Attachment 4, Scatterplot:

GGraph