Fontys Paramedic University of Applied Sciences

English Stream Physiotherapy

The validity of estimation equations to predict 1-RM in healthy active young adults of the lateral row strength machine

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Preface

This study was conducted as a graduation project honored and rewarded with a bachelor degree.
Mankind always felt the need to compare themselves with others. This is also and especially true when it comes to strength - but the fact of knowing how strong someone is also serves the purpose of knowing how to make training more effective for the same person. With the knowledge of testing strength correctly and providing individual training based on different percentages of a person's 1-RM depending on the goal to be achieved, we as physiotherapists can improve the health of our patients.
This is the reason why I find this topic so interesting, also considering that there is still a lot to learn about. I got even more inspired and motivated into this topic by realizing in my second internship how practical strength testing can be and how often the approach of estimating 1-RM is actually needed and used in daily work. It represents a great part of physiotherapy to activate people and to make them self-responsible for their actions and their bodies. Providing them with the right information for their training enables patients to independently function again and that is what I attributed my working approach to.

This thesis marks the last step on my way of becoming a physiotherapist. During the 4 years of studying in Eindhoven I did not only get to know future colleagues as I thought in the beginning, but also friends who finally became family to me. Studying abroad meant to extend my horizon and to get in contact with a lot of different cultures and nationalities. I can say for myself that I reached that goal and learned and experienced a lot of new things. Of course I did not only focus on learning things about the world and other countries far away but also about the country I was now living in. I had the pleasure to get to know the Dutch live style and mentality of openness and directness which I both learned to appreciate very much. It is also fascinating how Dutch people balance work and life while finding fulfillment in both of them. Many of the experiences and impressions will guide and accompany me beyond my studies.

Acknowledgements are given to my family and Stefan Haase for supporting me in writing my thesis, Paul Herzeg and Lisa Ariane Gitter for peer reviewing, and Chris Burtin for supervising.

Anja Gustke
Eindhoven, 3.06.2014

Abstract

Introduction: To professionally test strength 1-RM (one repetition maximum) measurements are often used. Although this is a valid measurement, it cannot be applied to all people because of medical restrictions. Several estimation equations have been established based on submaximal testing to elude 1-RM measurements, but their validity depends on multiple components. In this study their validity for healthy active young adults performing the lateral row strength machine is determined.
Method: 19 healthy active young adults (median 22 years) were tested for their 1-RM of the lateral row strength machine. A reiteration was induced with a weight closest to the subjects 80%RM. This weight and the attained number of repetitions until failure or fatigue were inserted into 15 equations. Correlations between 1-RM and estimated 1-RM were defined using Spearman’s test. Bland-Altman plots were drawn to investigate the estimation error.
Results: Statistically significant ($p<0,01$) high correlations ($>0,9$) were found for all equations. Almost all mean differences of the Bland-Altman plots were close to 0. Maximum of limits of agreements was 57,36kg and minimum -20,11kg. Mayhew’s et al. and Lombardi’s equations had limits of agreements closest to 0, and estimation errors were small (0,31kg and -1,10kg respectively), while Reynolds’ et al. had the greatest estimation error (31,42kg) and overestimated 1-RM by far.
Conclusion: The lateral row strength machine can validly be estimated by several equations. Mayhew’s et al. and Lombardi’s equation seem to be most valid.

Key words: validity, one repetition maximum (1-RM), lateral row, strength prediction, repetitions to fatigue, estimation equation

Table of content

1. Introduction

Strength is an important factor for athletes, but is certainly also important in rehabilitation programs.[1] As a matter of fact, strength is required in everyday life and therefore affects all people. There are several possibilities to measure strength. An actual strength determination in a laboratory setting requires special equipment, as for example an isokinetic dynamometer, as well as trained personal and is therefore often too expensive and sophisticated.[2] Multiple other tools have been developed such as a handheld dynamometer, a transducer, or a force plate.[3] The probably least expensive and complex way of testing muscle strength is the assessment of the one repetition-maximum (1-RM). 1-RM is defined as “the capacity of a defined muscle or muscle group to exert force against a resistance in a single maximum effort”,[4] applying a correct technique through the whole range of motion.[5] This has been a topic in research since more than 50 years.[6] Due to the fact that it measures strength functionally as well as dynamically in comparison to isometric testing[7], it is very often chosen as a measurement tool.[5,7] Percentages of the determined value of the 1-RM are used by coaches, instructors or physical therapists to establish individualized training, and in particular, strength programs.[8] Having a good strength program enables physiotherapists or instructors in general to not only improve the condition and health of the patient[9,10,11] but might also help to even prevent illnesses.[10]

However, it is not always possible to conduct a 1-RM test with all patients due to age or serious illness[6] as diabetes or cardiovascular diseases. Furthermore, it is not advisable to do a 1-RM test with untrained patients, because it puts a lot of stress on the musculoskeletal apparatus and increases the risk of muscular injuries.[4,12] Another critical aspect is that 1-RM testing requires a lot of time[4,8] and is impractical to apply for large groups.[4,12]

To elude 1-RM measures several predictive equations have been established to estimate the 1-RM from submaximal testing. According to Reynolds et al.[6] “these equations are all based on having subjects lift the greatest load as possible for a predetermined number of repetitions (such as in RM testing), a given load for as many repetitions as possible in a predetermined time frame, or with loads inducing fatigue within a specific range of repetitions”. They are said to have a strong linear relation considering the number of repetitions that can be completed with the submaximal testing and the percentage of the 1-RM.[13] However, this relation may only be considered as strong if the submaximal testing is performed with more than 75% of the actual 1-RM.[13] An advantage of the equations is that they can easily be included in normal training.[14] The validity of these equations has previously been investigated for various exercises. Most of the studies focused on free weights, examining the bench press and squat.[2,8,12,13,14.]Up to now, however, very little is known about the lateral row strength machine. When applying equations it has to be considered that the equations are influenced by a number of components including age, sex, training status or muscle group.[6,15] Consequently, the validity of these equations has to be acknowledged as population[6,15] and exercise specific.[6]

The purpose of this study was to gain further knowledge about the validity of estimation equations for a specific population group and a specific exercise which have not yet been examined in that combination. The obtained information could help physiotherapists and other professionals to further secure and optimize the accuracy and correctness of strength programs established on the basis of 1-RM estimations. In order to achieve that goal and gain valuable insight for daily practice it would be desirable to identify one equation which is valid over a range of several exercises and populations. Therefore this study investigates the validity of equations for healthy active young adults of the lateral row strength machine.

2. Method

2.1 Study design

This experimental validation study of 1-RM estimation equations was conducted in the gymnasium of the Fontys University at Theodor Fliednerstraat, Eindhoven, NL. 1-RM testing was done with a lateral row strength machine (Nautilus compound row, Vancouver, USA). The obtained value was taken to reckon 80% of the 1-RM, which constituted the weight basis for the reiteration of the exercise. Kilograms as well as number of repetition until failure or fatigue were filled into the estimation equations to calculate 1-RM. The obtained values from the estimation equations were compared to the actual 1-RM to assess their validity.

Subjects

Students from Fontys University of Applied Sciences Eindhoven (Physiotherapy English Stream) were contacted via e-mail (Appendix I) and direct individual conversation inviting them to participate in this study on a voluntarily basis. In the e-mail as well as in conversations, information about the experiment was given (Appendix II) and in- and exclusion criteria were clarified. For subjects to be included in the study they had to be young, healthy active adults, aged 18-35, being physically active at least two times a week. Next to strength training, activity included recreational sports training, cardiovascular endurance or interval training and any group sport activity. To participate in the study there had to be at least one day of rest between the last intensive rhomboid training and the testing. Reasonable understanding and speaking of the English language was also a presupposition. Students were not allowed to have any past (in the last year) or current injuries to the upper body, which would hinder them of performing the rowing exercises. In addition, they should not have any cardiovascular problems or other systemic diseases, which put them at risk while exercising. 28 subjects were willing to participate but due to exclusion criteria only 19 of them could be tested.

Research procedure

After signing an informed consent (Appendix III) and completing a questionnaire (Appendix IV), the subject cycled for 10 minutes on a stationary bike as a non-specific warming up. Following this, explanation of the position and performance of the exercise was given by the researcher while showing the exercise to the subject. For the measurement, an angle of 80° in the knees was attained. The test subject adjusted its sitting posture, maintaining a straight back throughout the whole exercise, to eliminate compensation as much as possible. Instruction was given to activate the abdominal muscles to maintain that posture. The subject grasped for the handlebars, pulled them in the direction of the body and stabilized them there for a short moment to regain a correct posture. The elbows were still kept extended in this position, although not fully. The exercise was performed with the shoulders kept low and wrists in neutral position, having the elbows in the mid position. The elbows were simultaneously brought backwards next to the body through the full range of motion. To help the subject carry out the right technique, instruction was given to bring the shoulder blades together, performing a retraction movement. When executing more than one repetition, the exercise was performed as previously explained, granting a correct technique through a full range of motion, while the elbow joints were never fully extended. The lateral row strength machine and the correct performance of the exercise are displayed in Figure 1. Furthermore, the subject was instructed on the breathing pattern during the exercise. The focus was put on the exhaling phase, which takes place during the concentric part of the exercise.[7]

Figure 1 lateral row strength machine used for testing (Fontys University gym)

The subject took a self-chosen weight, which was supposed to be light and with which he/she could manage 5 to 10 repetitions.[7] With this weight, eight repetitions were carried out to familiarize with the machine. Depending on training status, age and sex, a weight range from 16kg to 40kg was expected. Instructions and corrections were given by the researcher during the familiarization process, taking all previously explained factors into consideration. At a later stage, no further corrections and no verbal encouragement was given. Following this, the subject was given one minute rest[7] to process the information and recover.

The participating subject was categorized depending on its choice of weight for the familiarization process. A subject with a weight in the range of 16 - 23kg was placed in category 1, the one choosing a weight in the range of 25,3 - 36kg was assigned to category 2, and above 38,3kg was placed in category 3. Due to limitations of the machine, weight could only be increased in inconsistent intervals (Appendix V). It was thus decided to increase the weight in levels, differentiating between level 1 [1,5 - 2,5kg], level 2 [3,7 – 4,8kg], level 3 [6 – 7kg] and level 4 [8,2 – 9,5kg]. Based on these weight level increases, a protocol was developed (Appendix VI).

The testing procedure is presented in Figure 2. A warming up load was determined by taking the weight from the familiarization process, adding a level 2 weight for category 1, level 3 for category 2 and level 4 for category 3. Four repetitions were performed with this weight. For the following 1-RM measurement seven attempts were allowed. Each new 1-RM attempt implied a load increase within level 1 for a subject in category 1, level 2 for category 2 and level 3 for category 3. If, at a given moment, the subject failed or performed the attempt with compensation (not the whole range of motion, forward movement of the head, extension of the back, elevation of the shoulders, elbows not at the side of the body, lacking coordination in terms of searching for the correct movement), a new try was performed after the resting period. For this try, a weight from one level lower was added to the last valid attempt to create an intermediate stage. For example, a subject in category 2 managed one repetition with 50kg but failed at 54,5kg (level 2 weight increase), the next and last weight was set at 52,3kg (level 1 weight increase). If the subject failed again the 1-RM was determined as 50kg, if successfully performed, 52,3kg was defined as the subject's 1-RM - either way, the last correctly performed execution was reckoned the valid 1-RM. The described procedure was counted as one 1-RM attempt. For category 1, there was no intermediate stage.

The reiteration of the exercise was induced at 80% of the subject's 1-RM. Due to the fact that the smallest weight level consisted of 1,5kg, the weight closest to the subject's 80% was used. The number of repetitions, which could be expected to be around eight[7], was counted. The last valid repetition was regarded as the one that the subject was still able to perform through the whole range of motion with a correct technique, before the subject had to stop because of fatigue or had to be stopped because of compensation. The test results were filled into the estimation equations later on, for which the researcher needed the number of repetitions and the value of the subject's 80%RM in kilograms.

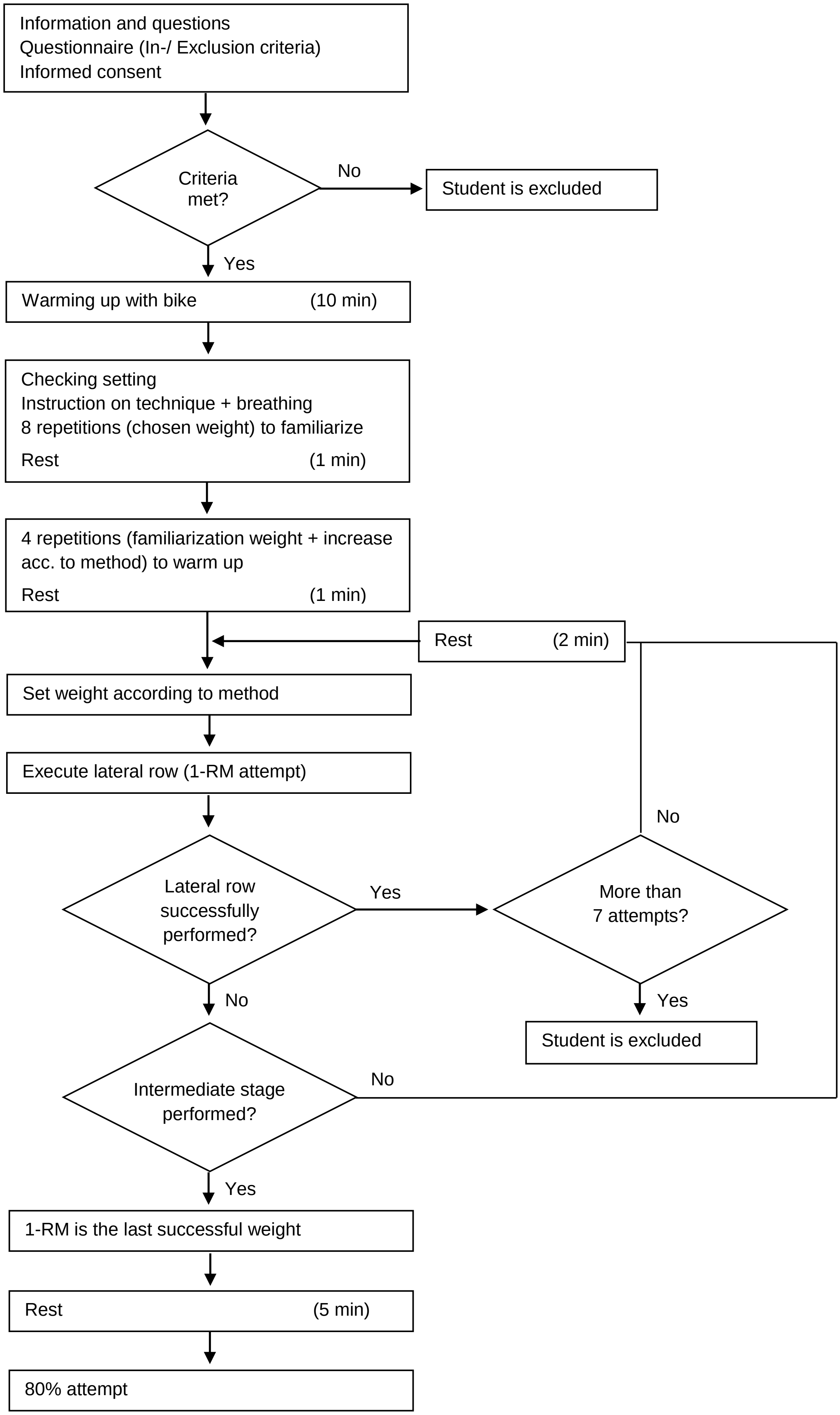


Figure 2 flow chart of research procedure

Estimation equations

Different equations were chosen to compare the estimated 1-RM to the actually obtained 1-RM. They take the repetitions to fatigue as well as the weight lifted into account for the prediction.[13] The estimations are presented in Table 1.

*Table 1 Equations for estimated 1-RM *(1-RME**)*

Author	**Equation (1-RME)**
Adams[5]	$1\text{-}RME = \frac{w}{(1-0{,}02r)}$
Berger[5]	$1\text{-}RME = \frac{w}{(1{,}0261-0{,}00262r)}$
Brown[5]	$1\text{-}RME = w \times (r \text{ X } 0{,}0338 + 0{,}989)$
Brzycki[5]	$1\text{-}RME = w \frac{36}{37-r}$
Cummings and Finn[5]	$1\text{-}RME = 1{,}175w + 0{,}839r - 4{,}29787$
Epley[8]	$1\text{-}RME = w \times \left(1 + \frac{r}{30}\right)$
Kemmler et al.[14]	$1\text{-}RME = w(0{,}988 + 0{,}0104r + 0{,}0019r^2 - 0{,}0000584r^3)$
Lander[8]	$1\text{-}RME = \frac{100 \times w}{101{,}3 - 2{,}67 \times r}$
Lombardi[5]	$1\text{-}RME = w \times r^{0{,}1}$
Mayhew et al.[16]	$1\text{-}RME = \frac{100 \times w}{52{,}2 + 41{,}9\, e^{-0{,}055 \times r}}$
O' Connor et al.[8]	$1\text{-}RME = w \times (1 + 0{,}025 \times r)$
Reynolds et al.[5]	$1\text{-}RME = \frac{w}{0{,}5551\, e^{-0{,}0723r+0{,}4847)}}$
Tucker et al.[5]	$1\text{-}RME = 1{,}139w + 0{,}352r + 0{,}243$
Wathen[8]	$1\text{-}RME = \frac{100 \times w}{48{,}8 + 53{,}8\, e^{-0{,}075 \times r}}$
Welday[5]	$1\text{-}RME = w(r \text{ X } 0{,}333) + w$

** 1-RM: one repetition maximum*
*** 1- RME: one repetition maximum estimation*
Note: r = number of repetitions, w = submaximal weight lifted

2.2 Data analysis

To process the data the computer programs SPSS (Statistical Package for the Social Sciences, IBM Corporation, Endicott, USA) version 21.0 and Excel 2010 (Microsoft Corporation, Redmond, USA) were used. The data obtained in this study was ratio data given in kilograms. It was found to be not normally distributed; consequently non-parametric testing was done, determining the median and the range. A Spearman correlation was defined to compare the estimated 1-RM values of the estimation equations to the real 1-RM measurement. The p-value was set at $\alpha = 0, 05$. Data was interpreted as statistically significant when $p<0,05$. For further investigation of the differences and deviations concerning the estimated values compared to the actual measured 1-RMs, Bland-Altman plots were made for all equations, displaying also limits of agreement, to determine the estimation error. Although 19 subjects were included in the testing, Bland-Altman plots only showed 17 dots because there were two pairs of subjects obtaining exactly the same amount of repetitions with the same amount of weights, being consequently identical measurements.

2.3 Ethical aspect

This study was conducted in accordance with the requirements of the METC (Medical Ethical Monitoring Committee). The participating subjects were well informed by means of an information letter and signed an informed consent. All data obtained in connection with and during the testing was kept and processed anonymously as well as its presentation to protect the subject’s rights and personal data.

3. Results

Of the 19 subjects tested, 11 were female and 8 male. 15 of them did strength training at least once a week. Other than strength training, subjects performed the following sports on a regular basis: football, swimming, basketball, handball, cricket, climbing, cross fit, field hockey, yoga, and cardio activities such as biking, spinning and running. The training volume of the subjects differed considerably (Table 2). The time ranges of training given by one subject were averaged to calculate the time spent on training by that one person. 6 subjects stated that they had the lateral row strength machine in their regular workout, ranging from once in two weeks to two times in one week, with a median of once a week. Further descriptive characteristics of the subjects can be found in Table 2.

Table 2 Descriptive characteristics of the subjects

	N*	Median	Minimum	Maximum	Range
Age in years	19	22	20	31	11
Height in cm	19	174	158	191	33
Weight in kg	19	68	55	97	42
Training volume in min**	19	300	120	960	840

**N: number of subjects*
*** minutes per week*

Concerning the 1-RM testing, 4 attempts were needed as a median to successfully determine the subject's 1-RM. The obtained 1-RMs of the subjects varied from 30kg to 98kg with a median of 50kg. Percentages of subject's 1-RM used for the reiteration of the exercise ranged from 77% to 83% with a median of 80%. The subjects performed as a median 8 repetitions with the individual assigned weight (as close as possible to 80% of the subject's 1-RM). Further information is given in Table 3.

Table 3 Descriptive characteristics of 1-RM (one repetition maximum) and the reiteration

	N*	Median	Minimum	Maximum	Range
1-RM** attempts	19	4	2	7	5
1-RM** (kg)	19	50	30	98	68
%RM for reiteration	19	80,1	76,67	83,34	6,67
Repetitions	19	8	5	12	7

**N: number of subjects*
*** 1-RM: one repetition maximum*

In Table 4 the descriptive characteristics of the 1-RME (one repetition maximum estimation) values achieved by the estimation equations are given. Except for Berger's and Reynolds' estimations the minimum values of the estimations were very close (a range of 2,69kg) to each other. Regarding the maximum, values were also very narrow (a range of 6,15kg), apart from those achieved by Berger's, Kemmler's et al. and Reynolds' et al. equations. Likewise, median values for all equations but Berger's, Kemmler's et al. and Reynolds' et al. were very narrow (a range of 3,14kg).

Table 4 Descriptive characteristics of 1-RM (one repetition maximum) estimations

Equation	**N***	**Minimum****	**Maximum****	**Range****	**Median****
Adams	19	27,38	92,21	64,83	47,09
Berger	19	22,88	78,69	55,81	40,19
Brown	19	28,87	96,86	67,99	49,47
Bryzcki	19	28,55	95,16	66,61	48,60
Cummings and Finn	19	29,44	94,75	65,31	49,16
Epley	19	29,13	97,80	68,67	49,95
Kemmler et al.	19	26,75	89,92	63,17	45,92
Lander	19	28,77	95,99	67,22	49,03
Lombardi	19	28,32	96,33	68,02	49,20
Mayhew et al.	19	29,05	98,25	69,21	50,18
O'Connor et al.	19	27,60	93,18	65,58	47,59
Reynolds et al.	19	45,50	145,95	100,44	74,54
Tucker et al.	19	29,26	93,03	63,77	48,84
Wathen	19	29,36	98,36	68,99	50,23
Welday	19	29,13	97,78	68,66	49,94

**N: number of subjects*
*** = given in kilograms*

The Spearman's test showed that all estimations had a very good correlation to the actual 1-RM, reaching values above 0,9. Furthermore, all correlations as listed in Table 5 were statistically significant with $p<0,01$.

Table 5 Spearman's test for the correlation of 1-RM (one repetition maximum) with 1-RME (one repetition maximum estimation)

equation	Correlation coefficient with 1-RM*	Sig. (2-tailed)***	N****
Adams	0,978**	0,00	19
Berger	0,988**	0,00	19
Brown	0,978**	0,00	19
Bryzcki	0,973**	0,00	19
Cummings and Finn	0,982**	0,00	19
Epley	0,978**	0,00	19
Kemmler et a.	0,978**	0,00	19
Lander	0,978**	0,00	19
Lombardi	0,985**	0,00	19
Mayhew et al.	0,982**	0,00	19
O'Connor et al.	0,978**	0,00	19
Reynolds et al.	0,906**	0,00	19
Tucker et al.	0,988**	0,00	19
Wathen	0,978**	0,00	19
Welday	0,978**	0,00	19

** 1-RM: one repetition maximum*
*** Correlation is significant at the 0, 01 level (2-tailed)*
**** Sig. (2-tailed) = significance (p-value)*
*****N: number of subjects*

An overview of the data from which the Bland-Altman plots were made of is given in Table 6. When mean difference is regarded, 10 equations tended to underestimate 1-RM, having negative values. Reynolds' et al. equation had the greatest estimation error (31,42kg) and upper limit of agreement (57,36kg). With a positive lower limit of agreement (5,48kg), it generally tended to overestimate the actual 1-RM. Berger's estimation achieved the lowest estimation error (-11,28kg) as well as lowest value of lower limit of agreement (-20,11kg). With the only negative value for the upper limit of agreement (-2,45kg) it underestimated 1-RM by far. The estimation error of Mayhew's et al. equation was small (0,31kg), having at the same time the smallest lower limit of agreement (-3,34kg). In comparison, Lombardi's equation reached an estimation error which was slightly further away from 0 (-1,10kg), but its upper limit of agreement (1,79kg) was the closest to 0. Both, Mayhew et al. and Lombardi, slightly over- as well as underestimated 1-RM.

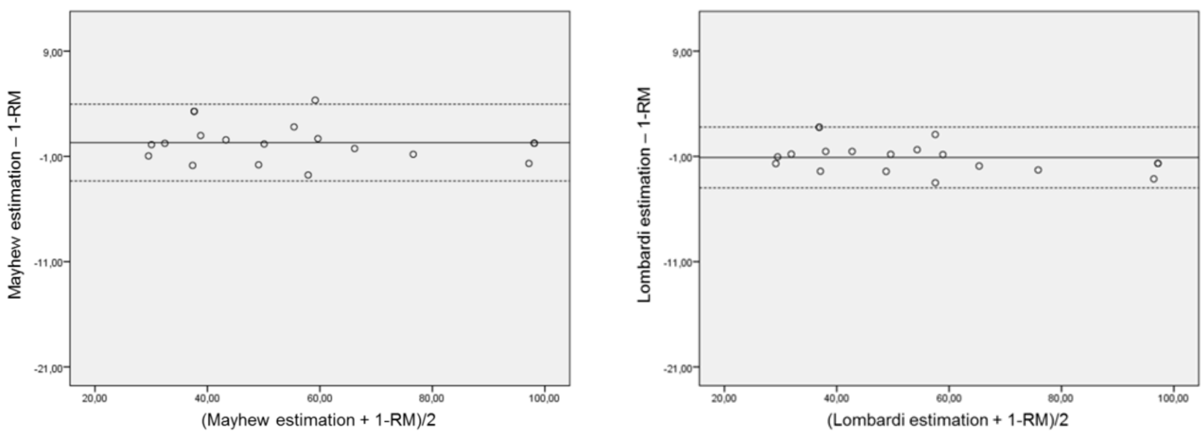
Further information on descriptive characteristics of Bland-Altman plots are to be found in the appendix (Appendix VII).

Table 6 Data for the illustration of Bland-Altman plots

Equation	**Mean difference 1-RME - 1-RM*'****	**Lower limit of agreement****	**Upper limit of agreement****	**Range****	**N*****
Adams	-2,82	-8,53	2,89	11,48	19
Berger	-11,28	-20,11	-2,45	17,66	19
Brown	-0,11	-5,41	5,18	10,59	19
Bryzcki	-0,61	-7,73	6,51	14,24	19
Cummings and Finn	-0,81	-5,36	3,74	9,10	19
Epley	0,39	-4,71	5,49	10,20	19
Kemmler et al.	-4,09	-10,61	2,44	13,05	19
Lander	-0,19	-6,98	6,60	13,58	19
Lombardi	-1,10	-3,99	1,79	5,78	19
Mayhew et al.	0,31	-3,34	3,96	7,30	19
O'Connor et al.	-2,46	-7,38	2,45	9,83	19
Reynolds et al.	31,42	5,48	57,36	51,88	19
Tucker et al.	-1,79	-6,02	2,43	8,45	19
Wathen	0,76	-4,63	6,14	10,77	19
Welday	0,38	-4,70	5,47	10,17	19

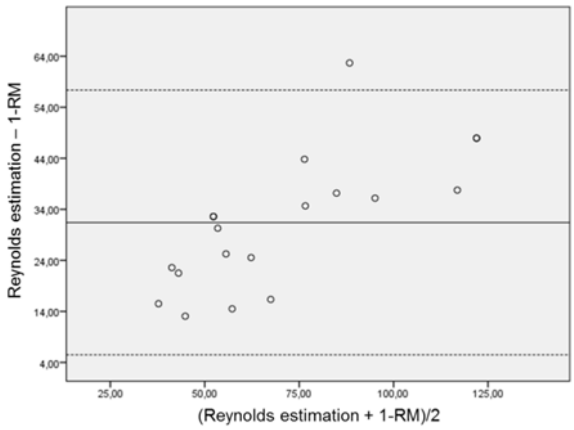
** 1-RM: one repetition maximum; 1-RME: one repetition maximum estimation*
*** = given in kilograms*
**** N: number of subjects*

The distribution of the estimations obtained by Mayhew's et al. equation (Figure 3) was quite regular lying above and beneath the mean difference, some even being on the line, but one also exceeding the limits of agreement. At about 65kg, estimations tended to lie more under the mean difference, but still within the lower limit of agreement. Also for Lombardi's equation (Figure 3) the distribution of the estimations was equally in terms of lying above and beneath the mean difference, having estimations on the line as well. Also this equation's estimations were lower than the mean difference when estimation exceeded 65kg. Estimation values of both equations were approaching 0, which would have been the perfect conformance between estimation and actual 1-RM.



1-RM: one repetition maximum Unit: kilograms
Figure 3 Bland-Altman plots of Mayhew et al. and Lombardi estimation equations

Attention has to be called when interpreting the Bland-Altman plot of the Reynolds et al. estimation equation (Figure 4). The scale of the y-axis had to be adapted to the wide spreading of the estimations. Also the scale of the x-axis had to be prolonged due to the high estimation values of Reynolds' et al. estimation. The distribution of the estimations was broad and one of them even exceeded the limits of agreement. In contrast to the other equations presented so far, estimations achieved by Reynolds et al. equation tended to lie beneath the mean difference with weights up to about 75kg and then changed abruptly, being then with the estimations above the mean difference.



1-RM: one repetition maximum *Unit: kilograms*
Figure 4 Bland-Altman plot of Reynolds et al. estimation equation

The other Bland-Altman plots are to be found in the appendix (Appendix VIII).

4. Discussion

The purpose of this study was to investigate whether estimation equations can validly predict 1-RM for the lateral row strength machine in healthy active young adults. All equations used were proven to be significantly correlated to the actual obtained 1-RM with values higher than 0,9. The p-value was highly statistically significant (p<0,01) for all equations. Mayhew's et al. and Lombardi's estimation equations were identified for having the smallest range of limits of agreements with a mean difference close to 0 and were therefore found to be the two best ones for estimating 1-RM. Since Reynolds' et al. equation highly overestimated 1-RM within a great range of limits of agreement, it might not be advisable to use it. The overestimation could lead to safety issues when applied in practice. However, due to a small sample size the results have to be interpreted with caution.

Although several other studies have been conducted examining the validity of 1-RM estimation equations for various exercises, the lateral row strength machine has not yet been much of a focus of investigation, even though it is commonly included in strength programs in physiotherapy. Only one other study by Kemmler et al.[14] could be identified investigating the lateral row, in which O'Connor's et al. equation has been shown to be the best for estimating the lateral row. This might be due to the fact that Kemmler et al.[14] had a very homogenous population of postmenopausal women in contrast to this study's young and gender mixed population. In addition, those women attended a two year training program before testing, altering their level of professionalism and familiarization with the machines.

High correlations (>0,9) between 1-RM and estimation equations have been confirmed for different exercises for the Adams[5], Berger[5], Brown[5], Bryzcki[6,8,12,13], Cummings and Finn[5], Epley[6,8,13], Kemmler et al.[5], Lander[6,8,13], Lombardi[5,6,8,13], Mayhew et al.[5,6,8,13], O'Connor et al.[5,6,8,13], Reynolds et al.[5,6], Tucker et al.[5], Wathen et al.[5,8,13] and Welday et al.[5], when repetitions to fatigue were fewer than 10. Also in other studies, Mayhew's et al. estimation equation has been found to be one of the most accurate equations for predicting 1-RM[5,8,13], but other equations have been shown to do so as well.[5,6,8,12,13,14] No study reported that Lombardi's or Mayhew's et al. equations were not to be used to predict 1-RM.[5,6,8,13] Even though Reynolds' et al. equation has been claimed in this current study to be not advisable to use, it was stated by Reynolds' et al.[6] that this equation had the smallest mean difference in their study. Reasons for these contradicting results could be the very broad population with a great age range and differing training experience. Moreover, Reynolds et al.[6] compared the leg press and chest press with different repetitions to fatigue and differently assigned %RM than in this study. Authors themselves outlined, that equations have to be used very carefully regarding specific exercise and population.[6]

It has to be pointed out, that currently available literature concerning the validity of 1-RM estimation equations differ in design not only in regard to which exercise[5,6,8,12,13,14] was investigated but also in regard to sample size[5,6,8,12,13,14], population characteristics[5,6,8,12,13,14], anthropometric data[5,6,12], number of repetitions[5,6,8,12,13] and assigned %RM.[5,6,12,13] Furthermore, there was a differing number and diversity of applied equations for comparison.[5,6,8,12,13] Additionally, it has to be kept in mind that there are differences in procedure for familiarization processes as well as warming up and resting times between sets and between exercises,[5,6,8,12,13] whether training was provided before the testing[5,13], whether encouragement was given[13] during the testing and whether free weights[5,6] or machines[6,13] were used. All these parameters have to be considered when comparing and interpreting results from other studies.

Strength trainings are frequently begun using machines[13] instead of free weights due to the fact that less core stabilization and control over the exercise are needed. Being more of a guided movement, compensation and therefore the risk of injury[17] can be reduced and a correct technique maintained throughout the testing more easily than with free weights. For all these reasons and because the row strength machine can easily be instructed and handled without a long learning process, the machine was preferred over free weights.

According to Carpinelli[18], 1-RM testing can be safely done with healthy subjects, if the exercise is controlled for correctness. The 1-RM testing procedure in this study was partly in accordance with the national strength and conditioning association (NSCA) protocol of 1-RM testing[7,19], which is an often used tool for measuring 1-RM.[3,7] In the original protocol, 4-9kg are added for each new 1-RM attempt. This represents a broad range and may possibly lead to very high weight increases. When it comes to reproducibility, the protocol leaves lots of space for assumptions regarding the weight increase. Therefore it was decided to adapt the protocol for this study. Categories were established to better individualize the load increase and still have a concretely set load increase. The categories were established in compliance with the researcher's expectations and experiences and possibly could have been different in another study. A positive aspect of this protocol was that in comparison to other studies[2,5,6,12,13] weight adjustments were not just estimated by any "professional", giving only little information on weight increase, but clearly defined. On the other hand, the researcher had to occasionally accept a high number of 1-RM attempts because the use of the protocol only allowed pre-determined weight increase. Despite that, a median of four attempts was achieved to successfully determine the subject's 1-RM. According to the NSCA protocol[7], the 1-RM should be found within three to five attempts. This condition was thus met.

For the reiteration of the exercise, 80% of the subject's determined 1-RM was supposed to be used to set the weight. Since the number of repetition of an exercise is inversely related to the load lifted[7], with less load more repetitions can be performed by a subject. According to Baechle[7], about eight repetitions could be expected with 80% RM, but due to the machine's weight levels it was not possible to adhere to 80% at all times. Nevertheless, percentage of 1-RM was always above 75% and still had a median of 80% while the median number of repetitions was indeed eight. Both, %RM and repetition number were of importance because of the recommendation to test submaximal for 1-RM with a load higher or the same than 75%[7,13] and with less or exactly 10 repetitions.[7,8,20] It has been stated that within this range lies "the most accurate relationship between percentages of the 1RM and the maximum repetitions possible".[7] In fact, Dohoney et al.[21] and Reynolds et al.[6] stated that even less than 7 repetitions should be used for submaximal testing. Both requirements of the recommendation have been fulfilled, indicating valuable results.

Another strong aspect was that this study compared a high number of estimation equations to each other. Still it has to be kept in mind when applying these equations, that they incorporate several varying components. This means that most equations are based on different populations[6,14,16] and sample sizes[6,14,16], on different %RM[6,14,16] and therewith different numbers of repetitions to fatigue.[6,14,16] They were further founded on different exercises[6,14,16], performed either with free weights[6,16] or machines[6,14,], while some of the authors provided training programs before testing[14,16] and others not.[6] However, most of the data from which the equations were emerged remain unknown.[5,6,13] although Mayhew et al.[5] argued that they are probably based on male populations and Wood et al.[13] claimed that many of the nowadays existing equations were extrapolated from preexisting charts with a lot of guessing. Nevertheless, Lander's, O'Connor's et al., Wathen's and Lombardi's equation were meant to be universal in their application.[6,13]

Recovery potential varies from person to person. In this study, it was decided on one day rest between last rhomboid training and testing because subjects were active young adults and probably need little time to recover. Still, this is a minimum time of resting and it can therefore not be guaranteed that all subjects had perfectly recovered from their last training. Also resting periods in between sets are very important for each person participating in strength training or strength testing. They are dependent on the training status of the individual but also on the relative load lifted.[7] The heavier the load lifted, the more rest is needed.[7] For strength exercises commonly a rest period of at least 2 minutes is required,[7] in the protocol of the NSCA 2-4 minutes are advised.[7,19] In between 1-RM attempts 2 minutes rest were provided since subjects trained on a regular basis. However, maximum recovery time was given between testing and reiteration.

Likewise, in order to not fatigue subjects too much before the testing, the familiarization process and the warming up with the strength machine were kept to a minimum. This might have had the consequence that subjects felt not familiar enough with the machine.[18] When further regarding the influence of fatigue, it has to be mentioned that because of the differences in number of 1-RM attempts and because of varying percentages of 1-RM for the reiteration, conditions for the reiteration might not have been the same for all subjects. It is unclear how far this affected the results.

The lateral row strength machine itself leaves space for bias in terms of not having a chest support, which means that the performance requires much more core stability. The arising question is whether this machine, requiring a lot of core stability, should be used by patients starting strength training and whether 1-RM testing on this machine can accurately reflect the training levels of the patient.

A limiting factor of this study might be that the researcher had no possibility to control the subject's daily activities before coming to the testing, so that it cannot be guaranteed that all subjects had the same baseline conditions. This does not only include all physical activity done previously to the testing and resting times, but also general condition as for example nutrition basis, psychological and psychosocial factors. Another point of concern is the small sample size with which this study was conducted. Results could have been different and more valuable in terms of generalization with more subjects. Apart from that, there could have been more estimation equations to compare as for example Abadie's equation mentioned by Reynolds et al.[6]

For clinical implication it is important to use specific equations for specific populations and exercises[6] considering free weights and machines. Further, for the equations, their guidelines and framework conditions should be taken into account as for example repetitions to fatigue[16] and the %RM to be used, because of the relation between those two.[7,13,20] Due to this study's results, that many of the equations tend to slightly over- as well as underestimate the actual 1-RM but in a small and acceptable range, it can be suggest that for estimating 1-RM of the lateral row for this population several equations can be used. Nevertheless, Reynolds et al. equation should be regarded with caution due to its high overestimation of 1-RM. This knowledge can be used to compile an accurate training program for patients to improve strength and therewith health.

For future research it can be advised to not only take a bigger sample size into consideration but to also be more cautious and concrete considering the pre-testing condition as mentioned earlier. In addition, anthropometric data could be used to further compare the estimation equations. Correlations could be defined regarding differences in predicting 1-RM for age, sex or training status considering training times, volume, specific kind of sports and whether or not strength training is performed on a regular basis. Moreover, it would be interesting to know whether there is a certain point or weight were an estimation equation changes from over- to underestimation, in other words whether there is a certain range of kilograms in which an equation works best. Investigation of the before named aspects could clarify if one of these factors influences the validity of prediction more than another. The question remains whether there is an equation which can validly predict 1-RM for the lateral row over a broad population, because this is needed in daily physiotherapeutic care. To have a complete picture of measurements of 1-RM and its estimations for the lateral row, it could be of further interest to conduct the same study or a similar one with the purpose of investigating inter- and intra-reliability.

5. Conclusion

For the lateral row exercise all investigated equations showed a high correlation to the actual 1-RM. In addition, estimation errors as well as limits of agreement were small for most of them. Consequently, most of the equations accurately estimated 1-RM. Mayhew's et al. and Lombardi's equations seem to result in the best outcomes for estimating 1-RM in healthy active young adults.

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7. Appendix

I. Invitation letter

The following is the e-mail which was sent to all English stream students to invite them to participate in this study.

Dear Student,

As every year around this time the 4th year students are preparing for their thesis project. Herewith I want to invite you to participate in my graduation research project, which will be about the assessment of 1 RM (one repetition maximum) and how to best estimate that value.

If I remember correctly, the assessment of the 1 RM is subject of period 9, so for those who can't (and do not have to) associate anything to it at this moment I would like to give a short explanation. The 1 RM is defined as the capacity of a specific muscle or muscle group to exert force against a resistance in a single maximum effort. This value is often used in strength programs to establish the perfect training level for you so that you will gain strength. And as you might have guest now, I will test your strength focusing on the rhomboids.

To help you to know the perfect amount of kilograms with which you should train your rhomboids and to help me with my project at the same time, it would be really great to see you. Furthermore I think it would be a nice opportunity for you to already get a taste of what it's like to be in the 4th year and to get some experience in how to conduct a study of your own. And remember –the 4th year will be coming sooner than you think ;)

Testing will be done in the gym of Fontys University (Theodor Fliednerstraat) , in the time of 19.03.14 – 21.03.14 and 25.+ 26. 03.14. Of course I will be flexible with the planning, so if you already know beforehand when it's best for you, let me know and I am sure we can arrange it. Testing will last about 1hour.If you are interested but you can't manage those days, contact me anyways please and I will see what I can do.

Since we are going to test you on your strength, I do have to mention here that there is always the possibility that you overload your muscles and that there might be following consequences such as muscle ache or strains or other injuries concerning muscles, ligaments or tendons. Regarding the fact that you are a healthy active person, this risk is kept very small.

Please read the attached information letter and if you have any further questions feel free to contact me either via mail: a.gustke@student.fontys.nl, or call me 06 49 855 395.

Hope to hear back from you and to see you in the gym of the Fontys University soon.

Regards,

Anja Gustke

II. Information letter

Estimation of 1 RM – information letter

Dear student,

Thank you for showing interest in my graduation project. Herewith I kindly like to ask you to participate in my study, investigating the 1-RM and its estimation possibilities focusing on the rhomboids.

It is my greatest concern that you read this information letter carefully in order to decide whether you want to take part in this research. If you have any further questions feel free to contact me. Contact information will be given at the end of this letter.

What is the aim of this research?

In my research I investigate the validity of 1-RM estimation equations, such as the Byrzick equation and others, to compare those outcomes with the actual 1-RM. It makes this study a validity study for the estimation equations. To know ones' 1-RM is important if you want to train and gain strength.

But because a 1-RM test, where you put all your effort into one single repetition of an exercise, is already strenuous for a healthy body, there are people for whom performing a 1-RM test can be dangerous. Therefore it is important, that the validity of estimation techniques is as good as possible. The aim concerning this is to have an accurate training program without having to test the actual 1-RM for those people.

How is the research conducted?

Once you have decided to participate, you will be asked for some personal data and your training habits. Since I want to compare the estimation equations' outcome for 1-RM with the actual attained 1-RM, I will test you on your 1-RM with the row strength machine. If we know your 1-RM, I will ask you again to do as many repetitions as you can with 80% of the weight you attained in the 1-RM. The number of repetitions and the kilograms of the 80% will be filled into the estimation equation by me later on to compare the outcomes.

Who can participate?

You are allowed to participate in this study if you are older than 18 but younger than 35 years. You need to be physically active at least two times a week (whereof at least one training has to be strength training) on a regular basis since more than 2 month and you may not have any past (in the last year) or current injuries to the upper body or others which hinder you to perform strength exercises with a row strength machine. As a last thing I would like to ask you to have your last training one day before the testing to give your body enough time to recover for the testing. Everyone meeting these criteria is more than welcome to participate and help me with my study.

Are there any risks?

According to Carpinelli [18], an article I read in connection with my research, 1 RM testing can be safely done with healthy subjects, if the exercise is controlled for correctness. But it should not be denied, that there is always the possibility that you overload your muscles and that there might be following consequences such as muscle ache or strains or other injuries concerning muscles, ligaments or tendons.

What are the advantages and disadvantages?

There is no other disadvantage than the maintaining really small risk of muscle ache. I only ask for 1 hour of your time, but since we are in the Fontys setting, you have the possibility to either go on with training afterwards at the sports center or to study or have a nice chat with the others. As an advantage I can point out that you will get kind of a personal training with instructions on how to perform the exercise correctly. After the testing you will know on which load you should train and I can probably give you some further tips.

If you wish I can also inform you about the outcomes of my study. Then you will know for the next time when you assess your training load whether you should do another 1-RM test or whether estimation by using an equation and which equation is sufficient.

Participation will as well give you a good first impression and already some experience about the thesis study, which you have to conduct yourself like this or similar in the 4th year.

What happens with the data?

The data will be kept anonymous and cannot be related to you as a person. Of course it will be seen and processed by me.

I hope to have you sufficiently informed. If you would like to know more feel free to contact me.

Hope to see you soon, Anja

Contact information:

Anja Gustke, a.gustke@fontys.nl, 0649 855 395

III. Informed consent

Agreement about the participation in the graduation study concerning the validity of 1-RM estimations

I have read the information letter about the research project attentively and have been informed another time orally about the research procedure and its risks. Al my questions have been answered sufficiently.

I participate voluntary and know that I have the right to stop my participation at any given time without any further comment or given reasons.

I know that the in the research involved people (researcher and supervisors) will have access to my data and that my data will be further processed. I have been reassured, that my personal data will otherwise be handled confidently. I give permission that my data can be used in this research project for the aims described.

I herewith declare to be accord with all mentioned aspects and I agree to participate.

Name participant: ....   Signature participant: ………………..

Date: …../ …../ ……….

I state that I have informed the participant the best that I could about the project, the project procedure and risks.

I there should be any changes during the time of the testing, before or after, I will inform my participant about those changes. If this should change the participants further agreement to this study, this contract will be made invalid.

Name researcher: ....   Signature researcher: ………………..

Date: …../ …../ ……….

Additional information, if necessary, is given by (if applicable)

Name: ....   Signature : ………………..

Function: Date: ..../...../........

IV. Pre-testing data collection

The following is the questionnaire which is handed to the participating students to collect anthropometric data.

Name: *Sex:*

Date of birth: *Height:*

Weight:

Training status (how often and how long do you train?):

Which sports do you do on a regular basis?:

Is the lateral row machine included in your regular training program?

If so, how often do you train with it in one week?

When was your last training and what did you do?

Have you had injuries to the upper body in the past last year?:

Are there any injuries to the upper body now?

Do you have a systemic illness like diabetes or cardiovascular problems or others which hinder you to perform rowing exercises or strength training in general?

I hereby declare that the information given above is true.

Signature: ……………….. Date: …../ …../ ……….

V. Weight increase of the lateral row strength machine

Due to limitations of the machine, weight could only be increased in inconsistent intervals (Table 7).

Table 7 Weight increase of the lateral row strength machine

Weight increase	**Weight (kg)**	**Weight increase** *(continued)*	**Weight (kg)** *(continued)*
1	16,0	24	68,5
2	18,3	25	71,0
3	20,5	26	73,3
4	23,0	27	75,5
5	25,3	28	77,0
6	27,5	29	79,3
7	30,0	30	81,5
8	32,3	31	84,0
9	34,5	32	86,3
10	36,0	33	88,5
11	38,3	34	91,0
12	40,5	35	93,3
13	43,0	36	95,5
14	45,3	37	98,0
15	47,5	38	100,3
16	50,0	39	102,5
17	52,3	40	105,0
18	54,5	41	107,3
19	57,0	42	109,5
20	59,3	43	111,0
21	61,5	44	113,3
22	64,0	45	115,5
23	66,3		

VI. Research protocol

1) Self-chosen light weight for familiarization process, subject should be able to perform 5-10 reps. 8 repetitions are performed. Corrections for performance are given.

   Weight used for the 8 repetitions =

2) 1 min rest
3) 1-RM testing

execution	**Category 1** (16 – 23kg)*	**Category 2** (25,3 – 36kg)*	**Category 3** (>38,3kg)*
Weight increase per attempt	+ Level 1	+ Level 2	+ Level 3
warming up (4 reps)	familiarization weight + Level 2	familiarization weight + Level 3	familiarization weight + Level 4
	1 min rest	1 min rest	1 min rest
1-RM (1)	Warming up weight + Level 1	Warming up weight + Level 2	Warming up weight + Level 3
	2 min rest	2 min rest	2 min rest
1-RM (2) If applicable: Intermediate stage	RM1 + Level 1	RM1 + Level 2 (2 min rest) RM1 + Level 1	RM1 + Level 3 (2 min rest) RM1 + Level 2
	2 min rest	2 min rest	2 min rest
1-RM (3) If applicable: Intermediate stage	RM2 + Level 1	RM2 + Level 2 (2 min rest) RM2 + Level 1	RM2 + Level 3 (2 min rest) RM2 + Level 2
	2 min rest	2 min rest	2 min rest
1-RM (4) If applicable: Intermediate stage	RM3 + Level 1	RM3 + Level 2 (2 min rest) RM3 + Level 1	RM3 + Level 3 (2 min rest) RM3 + Level 2
	2 min rest	2 min rest	2 min rest
1-RM (5) If applicable: Intermediate stage	RM4 + Level 1	RM4 + Level 2 (2 min rest) RM4 + Level 1	RM4 + Level 3 (2 min rest) RM4 + Level 2
	2 min rest	2 min rest	2 min rest
1-RM (6) If applicable: Intermediate stage	RM5 + Level 1	RM5 + Level 2 (2 min rest) RM5 + 1 Level	RM5 + Level 3 (2 min rest) RM5 + 2 Level
	2 min rest	2 min rest	2 min rest
1-RM (7) If applicable: Intermediate stage	RM6 + Level 1	RM6 + Level 2 (2 min rest) RM6 + Level 1	RM6 + Level 3 (2 min rest) RM6 + Level 2
	5 min rest	5 min rest	5 min rest

** dependent on familiarization weight*

Determined 1-RM:

4) 80% attempt (8)

Weight	**reps**	**Compensation mechanism**

Compensation mechanism: ante flexion head/cervical spine, back extension, shoulder elevation, elbows not at the side of the body, wrist movement, coordination, not full ROM)
Fatigue

VII. Data of Bland-Altman plots

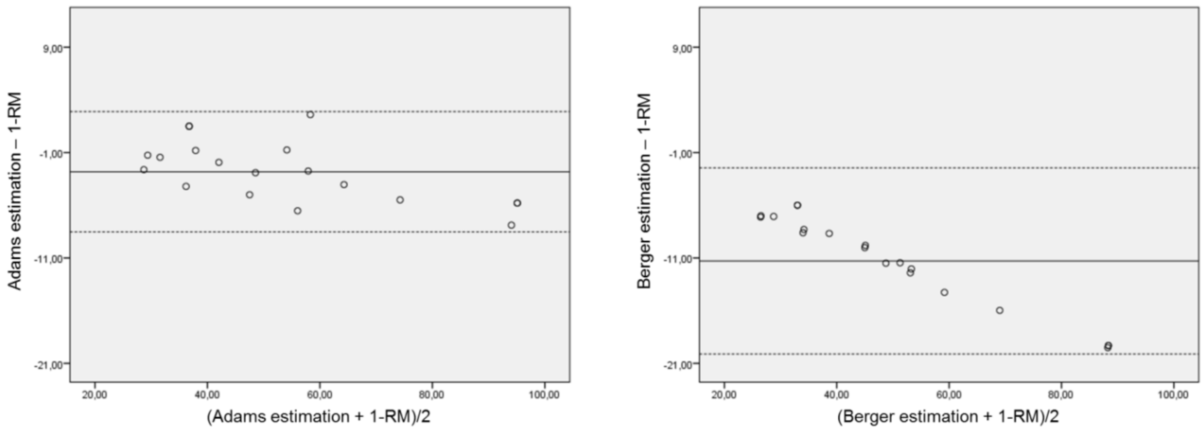
Table 8 gives further in-detail information about the Bland-Altman plots.

Table 8 Descriptive characteristics of Bland-Altman plots

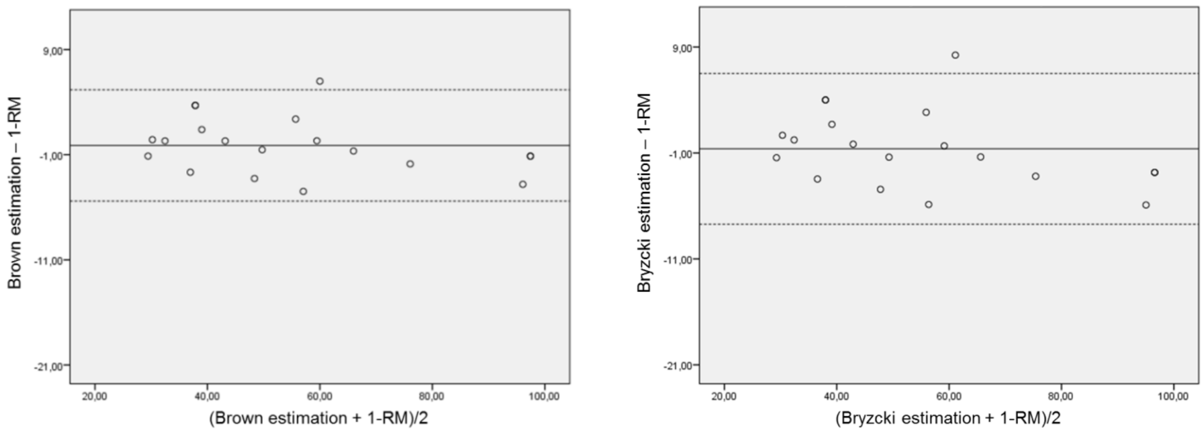
	N	**Minimum**	**Maximum**	**Range**	**Median**
Mean Difference	19	-11,28	31,42	42,7	-0,61
Upper limit of agreement	19	-2,45	57,36	59,81	3,96
Lower limit of agreement	19	-20,11	5,48	25,59	-5,41

** N: number of subjects*

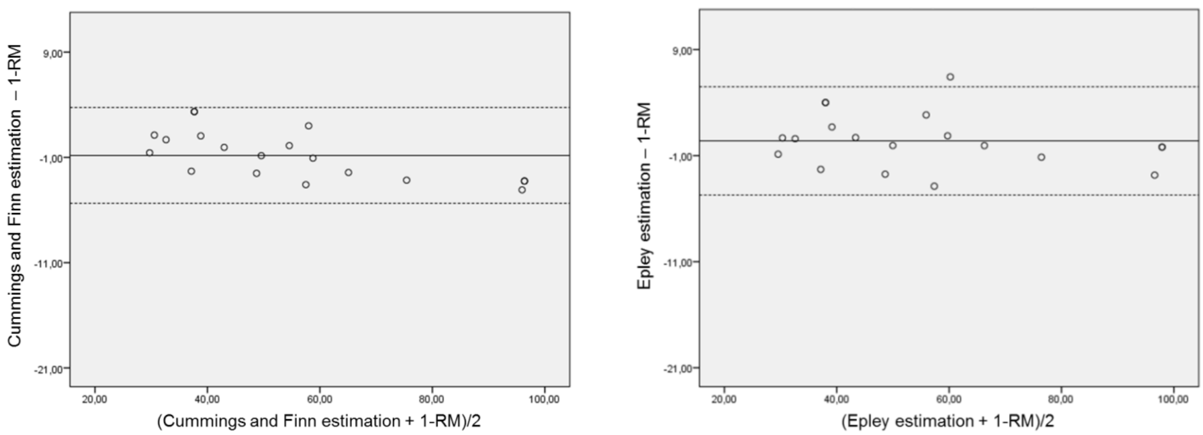
VIII. Bland-Altman plots



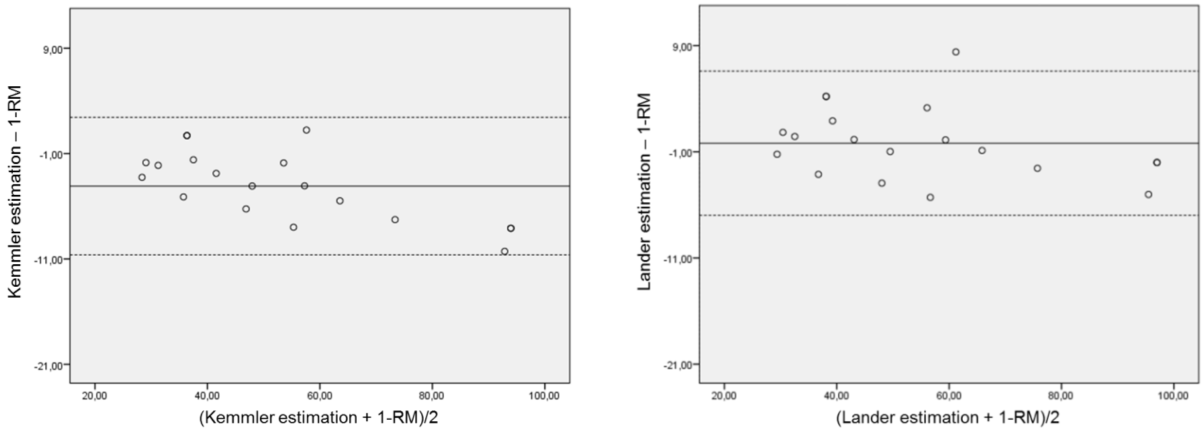
1-RM: one repetition maximum *Unit: kilograms*
Figure 5 Bland-Altman plots of Adams and Berger estimation equations



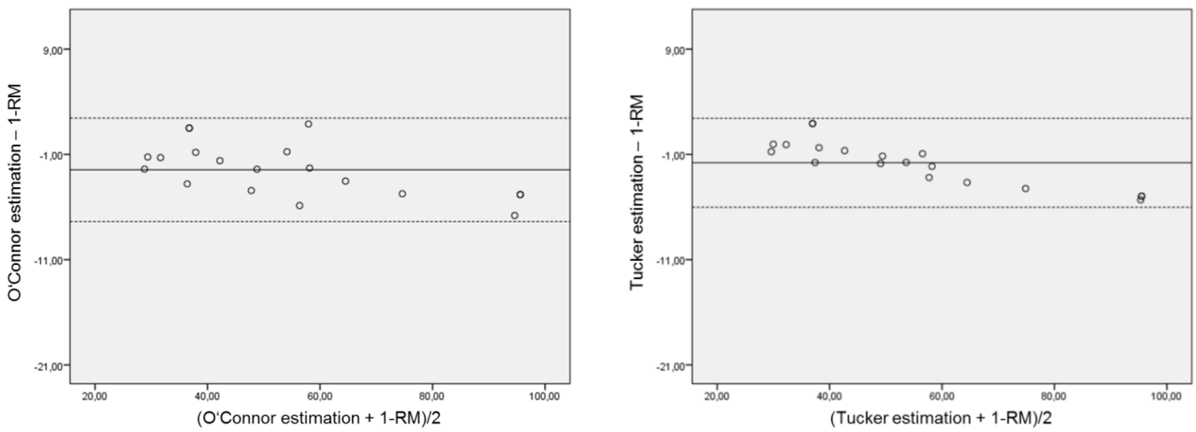
1-RM: one repetition maximum *Unit: kilograms*
Figure 6 Bland-Altman plots of Brown and Bryzcki estimation equations



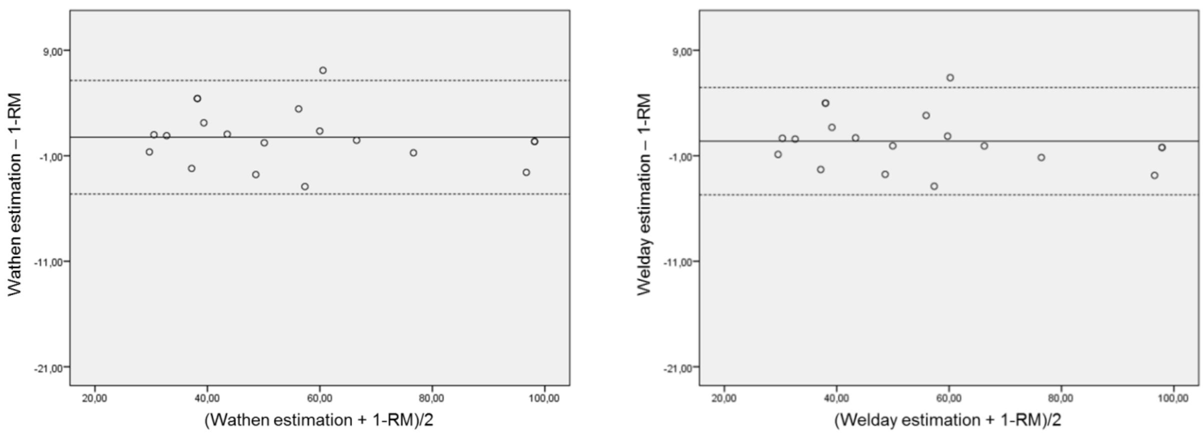
1-RM: one repetition maximum *Unit: kilograms*
Figure 7 Bland-Altman plots of Cummings and Finn and Epley estimation equations



1-RM: one repetition maximum *Unit: kilogrms*
Figure 8 Bland-Altman plots of Kemmler et al. and Lander estimation equations



1-RM; one repetition maximum *Unit: kilograms*
Figure 9 Bland-Altman plots of O'Connor et al. and Tucker estimation equations



1-RM: one repetition maximum *Unit: kilograms*
Figure 10 Bland-Altman plots of Wathen and Welday estimation equations

IX Comparison of estimation equations

Since there are several estimation equations for the determination of 1-RM, it is conclusive that these equations lead to estimations of differing values, being closer or further away from the actual 1-RM and therewith have different accuracies.

In Figure 11, all estimation equations are presented to show their deviations. For this example a repetition of eight is presumed, while the amount of weight lifted increases by 5 kilograms. It becomes visible, that there is a number of equations which are very close to each other while two of them (Reynolds, Berger) protrude. At a weight of 40 kilograms, the estimated values for the 1-RM differ up to 39,5kg (i.e. 98,75%).

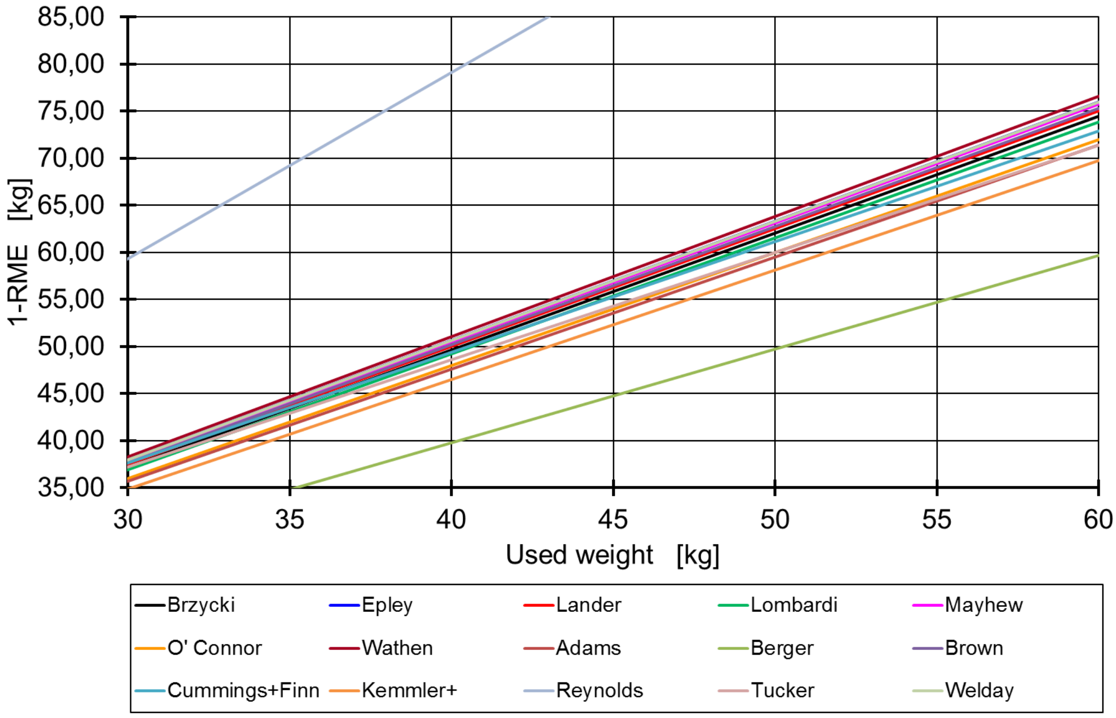


Figure 11 graphical plot of different 1-RME equations at a constant repetition number of eight

X. Confidentiality statement

Name: Anja Gustke Student No°: 2158903

Title: **The validity of estimation equations to predict 1-RM in healthy active young adults of the lateral row strength machine**

Content (description)**:**

Introduction: To professionally test strength 1-RM (one repetition maximum) measurements are often used. Although this is a valid measurement, it cannot be applied to all people because of medical restrictions. Several estimation equations have been established based on submaximal testing to elude 1-RM measurements, but their validity depends on multiple components. In this study their validity for healthy active young adults performing the lateral row strength machine is determined.

Method: 19 healthy active young adults (median 22 years) were tested for their 1-RM of the lateral row strength machine. A reiteration was induced with a weight closest to the subjects 80%RM. This weight and the attained number of repetitions until failure or fatigue were inserted into 15 equations. Correlations between 1-RM and estimated 1-RM were defined using Spearman's test. Bland-Altman plots were drawn to investigate the estimation error.

Results: Statistically significant ($p<0,01$) high correlations ($>0,9$) were found for all equations. Almost all mean differences of the Bland-Altman plots were close to 0. Maximum of limits of agreements was 57,36kg and minimum -20,11kg. Mayhew's et al. and Lombardi's equations had limits of agreements closest to 0, and estimation errors were small (0,31kg and -1,10kg respectively), while Reynolds' et al. had the greatest estimation error (31,42kg) and overestimated 1-RM by far.

Conclusion: The lateral row strength machine can validly be estimated by several equations. Mayhew's et al. and Lombardi's equation seem to be most valid.

1. By signing this Statement, the Fontys Paramedic University of Applied Sciences in Eindhoven commits itself to keep any information concerning provided data and results obtained on the basis of research of which is taken cognizance as part of the above practical research project and of which it is known or can be reasonably understood that said information is to be considered secret or confidential, in the strictest confidence.
2. This confidentiality requirement also applies to the employees of the Fontys Paramedic University of Applied Sciences, as well as to others who by virtue of their function have access to or have taken cognizance of the aforesaid information in any way.
3. The above notwithstanding, the student will be able to perform the practical research project in accordance with the statutory rules and regulations.

Student:

Name: Anja Gustke

____

(signature) Date: 3/06/2014

Supervisor:

Name: Chris Burtin

____

(signature) Date:__/__/_____

Coordinator: for receipt

Name: Chris Burtin

____

(signature) Date:__/__/_____

XI. Conveyance of rights agreement

AGREEMENT

Pertaining to the conveyance of rights and the obligation to
convey/return data, software and other means

The undersigned:

1. Ms Anja Gustke, residing at 5641 TH Eindhoven at the Radiostraat 32, hereinafter to be called “**Student**”

and

2. Fontys Institute trading under the name Fontys University of Applied Sciences, Rachelsmolen 1, 5612 MA Eindhoven, hereinafter to be called “**Fontys**”

CONSIDERATION

A. Student is studying at the Fontys Paramedic University of Applied Sciences in Eindhoven and is performing or will perform (various) activities as part of his/her studies, whether or not together with third parties and/or commissioned by third parties, as part of research supervised by the lectureship of Fontys Paramedic University of Applied Sciences. The aforesaid activities will hereinafter be called “**Lectureship Study Activities**”. At the time of the signing of this Statement, the Lectureship of Fontys Paramedic University of Applied Sciences supervises in any case the studies listed in Appendix 1, but this list is not an exhaustive one and may change in the future.

B. It is of essential importance to Fontys Paramedic University of Applied Sciences that (the results of) the Lectureship Study Activities can be further developed and applied without any restriction by Fontys Paramedic University of Applied Sciences and/or used for the education of other students. Fontys wishes in any event – but not exclusively – (i) to be able to share with and/or convey to third parties (the results of) the Lectureship Study Activities, (ii) to publish these under its own name, where the Student may be named as co-author providing that this is reasonable under the circumstances, (iii) to be able to use these as a basis for new research projects.

C. In case intellectual ownership rights and/or related claims on the part of Student will be/are attached to (the results of) the Lectureship Study Activities, parties wish – taking into account that which was mentioned under (B) – Fontys Paramedic University of Applied Sciences to be the only claimant with regard to said rights and claims. The Student therefore wishes to convey all his/her current and future intellectual property rights as well as related claims concerning (results of) the Lectureship Study Activities to Fontys, subject to conditions to be specified hereafter;

D. Student furthermore wishes to enter into the obligation – again taking into account that which was mentioned under (B) – to convey all data collected by him/her as part of the (results of) the Lectureship Study Activities to Fontys and not to retain any copies thereof, and also to return all data, software and/or other means previously provided by Fontys as part of (the results of) the

Lectureship Study Activities, such as measuring and testing equipment, to Fontys without retaining copies thereof, all the above being subject to conditions to be specified hereafter.

AGREE THE FOLLOWING

1. Conveyance of intellectual property rights

1.1 Student herewith conveys to the Fontys Paramedic University of Applied Sciences all his/her current and future intellectual property rights and related claims concerning (the results of) the Lectureship Study Activities, for the full term of these rights.

1.2 Intellectual property rights and/or related claims are understood to refer to, in any case – but not limited to – copyright, data bank law, patent law, trademark law, trade name law, designs and model rights, plant breeder's rights, the protection of know-how and protection against unfair competition.

1.3 The conveyance described under 1.1 shall be without restriction. As such, the aforesaid conveyance shall include all competences related to the conveyed rights and claims, and said conveyance shall apply to all countries worldwide.

1.4 Insofar as any national law requires any further cooperation on the part of Student for the conveyance mentioned under 1.1, Student will immediately and without reservation lend such cooperation at first request by Fontys Paramedic University of Applied Sciences

1.5 Fontys accepts the conveyance described under 1.1.

2. Waiver of personal rights

2.1 Insofar as permitted under article 25 'Copyright' and any other national laws that may apply, Student waives his/her personal rights, including – but not limited to – the right to mention Student's name and the right to oppose any changes to (the results of) the Lectureship Study Activities. If and insofar as Student can claim personality rights pursuant to any national laws notwithstanding the above, Student will not appeal to said personality rights on unreasonable grounds.

2.2 In deviation from that which was stipulated under 2.1, the Fontys Paramedic University of Applied Sciences may decide to mention the name of Student if this is reasonable in view of the extent of his/her contribution and activities.

3. Compensation

Student agrees that he/she will receive no compensation for the conveyance and waiver of rights as described in this Statement.

4. Guarantee concerning intellectual property rights

Student declares that he/she is entitled to the aforesaid conveyance and waiver, and declares that he/she has not granted or will grant in future, license(s) for the use of (the results of) the Lectureship Study Activities in any way to any third party/parties. Student indemnifies Fontys from any claims by third parties within this context.

5. Obligation to convey/return data, software and other means

5.1 At such a time as Student is no longer performing any Lectureship Study Activities and/or is no longer a student at Fontys, Student is obliged to convey to Fontys all data, in the widest sense of the word, collected by him/her as part of (results of) the Lectureship Study Activities, including – but not limited to – studies and research results, interim notes, documents, images, drawings, models, prototypes, specifications, production methods, process descriptions and technique descriptions.

5.2 Student guarantees not to have kept any copies in any way or form of the data meant under 5.1

5.3 Student is obliged to return to Fontys all data, software and other means provided to him/her by Fontys as part of the Lectureship Study Activities, and guarantees not to have kept copies in any way or in any form, of the provided software and/or other means.

5.4 Student agrees that if he acts and/or proves to have acted contrary to the obligations mentioned under 5.1 up to and including 5.3, (a) he/she shall be liable for all and any damages incurred or to be incurred by Fontys, and (b) that this will qualify as fraud and that Fontys can apply the appropriate sanctions hereto. The sanctions to be applied by Fontys may consist of, among other things, the denying of study credits, the temporary exclusion of the Undersigned from participation in examinations, but also the definitive removal of the registration of the Undersigned as a student at Fontys.

6. Waiver

Student waives the right to terminate this Agreement.

7. Further stipulations

7.1 Insofar as this Agreement deviates from the Student Statute, this Agreement shall prevail.

7.2 This Agreement is subject to Dutch law. All disputes resulting from this statement will be brought before the competent judge in Amsterdam.

Student:	**Fontys Institute** **trading under the name Fontys Hogescholen** **Supervisor:**
Name: Anja Gustke	Name: Chris Burtin
___________________________________	___________________________________
(signature) Date: 3/06/2014 Place: Eindhoven, NL	(signature) Date:__/__/_____ Place: ___________________

I, Ms. M.H. de Waard, sworn translator for the English language registered at the Court in Groningen, the Netherlands, and registered in the Dutch Register of Sworn Translators and Interpreters (Rbtv) under nr. 2202, herewith certify the above to be a true and faithful translation of the attached Dutch document into the English language.

Groningen, 23 May 2012,

[M.H. de Waard]