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THE ESTIMATION OF MAXIMUM EFFORT IN WEIGHT LIFTING PROCESSES

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Abstract: *Starting from defining the processes connected to lifting weights this article wishes to accomplish a quantitative analysis applied to the lifting processes. Also, based on the data collected at the recently ended Olympic Games (Beijing 2008) we build several models of analyzing the effects that some factors can determine during these processes.*

Key words: *estimation; effort; metric; processes*

1. Lifting processes

There are many fields in which the lifting force of objects characterized by weight, shape and volume intervenes. In most of the activities that meet the human factor is important to establish overlapping maximum effort that a certain person is submitting.

Effort is characterized by:

- intensity; is the degree of application of the body during activities of lifting, is expressed differently depending on the sport considered;

- duration, means the time frame during which effort is made;
- repeat frequency; is the number of activity repeats in a time unit;
- way of pursuit; represents all the conditions in which the activity is unfolding; for cycling, a track and favorable atmospheric conditions are needed, for gymnastics a covered gym and matrices are need.

For clarifications situations in which lifting processes occur are presented.

In sport branches there are:

- weight lifters who try to lift a maximum weight in one attempt; presently there are two types of lifting methods "clean and jerk" and „the snatch";
- the weight throwers use when throwing metallic balls with a weight of 7,248 kg;
- the hammer throwers; are similar to the weight throwers the only difference being that they use metallic balls attached with a cable to the handle, and the throw is made after several turns around their axis;
- the javelin throwers launch a spear; the antic trial requested that the javelin will stick into the ground otherwise the throw would have been null;
- the disc throwers are appreciated for the distance they throw the disc as for their precision.

In the current activity the weight lifting and transport processes are frequent:

- in constructions brick lifting, concrete bags, water buckets, beams, gravel, sand.
- in the wood industry log lifting, cupboards, wastes, boards, sawdust.
- in sports there are branches that assume lifting weights, own body, weights in extreme sports.

The lifting process has associated a formalization which includes:

- variables;
- driving or driving systems;
- objects meant for lifting;
- defining the conditions.

This approach considers the characteristics of the human factor, the one that executes the lifting processes. Taking in account the industrial growth, human strength is replaced by different mechanical, electrical equipments or for a short time now the computer assisted coordination of movements and lifting force. The development of robots assumes lifting force establishment models, which are treated distinctly in robotic science.

2. Factors that influence the lifting process

Persons are different from one another considering:

- age;
- sex
- height;
- weight;
- conformation;
- training;
- race;
- abilities.

In a certain context a person executes a lifting process successfully if:

- it fulfils the set objective;
- after committing its state is good and has the capacity of doing other activities;
- the lifting process took place in the established time frame;
- the movement of the object on the agreed upon trajectory was done without interruption.

The lifting effort is defined as being the minimum quantity of energy that needs to be consumed by a person on order to lift an object of a certain weight. Because persons are different, for the same weight of an object the efforts are different. Because of this an effort measurement based on the size of the produced effect, meaning based on the weight of the lifted object is needed.

To compute the effort the formula is used:

Effort = a_0 + a_1*Person weight + a_2*Person height + a_3*Person age

It results that the factors that influence the effort must be extended to include the particularities of the persons.

The following variables are defined

v – age because experimentally it is known that the lifting capacity is reduced until the person becomes an adult, reaches a peak when the person is mature, and decreases as the person ages;

g – the weight influences the degree of effort that a person makes in the lifting process, because in normal conditions the muscular mass has a significant weight in the body mass, and considering an adequate training that muscular mass develops and increases the weight lifting capacity of the person;

i – height is a characteristic strictly tied to the biological traits of a person, making a tight correlation with the bone system, which forms components that define drives in the lifting processes; the bone system has a specific consistency, influenced by the accumulation of basic organism components.

It means that the effort a person can realize is given by a relationship.

$e = f(v,g,i)$

In order to build effort estimation models the following hypothesis are considered:

- measurements are made based on the same procedures for all persons; the procedures define instruments with the help of which measurements are made, the conditions a person must fulfill to be measured, the optimal position of the person when the person is measured and the result processing method; the procedures must ensure result reproducibility for the persons measured in a collectivity; it means that by comparison, when the procedures are well defined the obtained results must not differ significantly if two teams make measurements independently for the same person collectivity;
- a homogenous community is considered, formed from persons that correspond to restrictions or filters which oversee belonging to an age group, a weight group, the duration of executing several activities which suppose weight lifting effort belonging to a specific interval, it is imposed to make measurements and build models separately for men and women;
- the weight and height are measured using the well established and validated procedures for persons from the homogenous community; the homogeneity is determined empirically using an estimation set given by specialists and adapted to any other characteristic defined for the elements of the collectivity, a collectivity formed from persons with an average height of 185 centimeters, is considered by specialists to be homogenous is the persons have heights ranging in [182,5; 187,5]; by elementary computation the correspondence is made such that these empiric results are considered for age and weight; average weight is 100 kg and the interval that ensures homogeneity is [97,3; 102,7]; average age is 30 years meaning 360 months which means that in order to form a homogenous collectivity the age must be in the interval [355;365] months;

- only the persons that don't use helping substances are considered, which respect a certain effort and recovery program; considering the fact that during the day the physiological characteristics of a person are changed, the capacity to sustain effort varies; it is important to make a study in order to determine the way in which effort and rest are alternating to maximize the efficiency of each person.

Considering the fact that in order to collect personal data for the persons that make up the homogenous collectivity are dispersed in the territory, the ones that operate the selection process must prove that they understand the measuring procedures and it will not be needed to redo the process to have the needed data for the estimation.

The data must be complete, correct and reproducible. The completeness assumes that in the table that contains the identification code of the person, height, weight, age must be marked as numeric values corresponding to the above characteristics. Empty spaces or lines that mark the lack of measurements for a person won't be allowed.

Correctitude assumes the use of calibrated measuring tools according to the existing standards, ensuring the correct position of the person in agreement with the information provided in the procedure and reading the data from the measuring tool. Reproduction requests that for the same characteristic of a person, regardless of who makes the measuring the result will be the same.

Considering the fact that the objective is to estimate the maximum lifting effort, it is carried on to processing the data for the persons that belong to a sport collectivity, specialized in lifting weights. To ensure the homogeneity of a sport collectivity in report to the maximum level of training, the collectivity is formed by the weight lifters who participated at the Olympic Games in Beijing 2008.

3. Building the models

In a general form, the technology for building estimation models assumes establishing the influence factors F_1, F_2, ..., F_k associated to lifting processes. The number of K factors is given by the capacity of the specialist which analyzes the process and by his experience. For example K=3, F_1 is the age, F_2 is the height and F_3 is the weight.

The interdependencies of the factors F_1, F_2, ..., F_k are analyzed by computing the correlation coefficients between the factors F_i and F_j.

$$r(Fi,Fj) = \frac{\sum (f_i - \bar{f}_i)(f_j - \bar{f}_j)}{\sqrt{\sum (f_i - \bar{f}_i)^2 \sum (f_j - \bar{f}_j)^2}}$$

where *f* denotes the values recorded for each factor.

Table 1. Correlation matrix for considered factors where $r(F_i, F_j)$ $1 \geq i > j \geq k$

	F_1	F_2	...	F_i	...	F_k
F_1	1	$r(F_2, F_1)$	...	$r(F_i, F_1)$	...	$r(F_k, F_1)$
F_2		1	...	$r(F_i, F_2)$	...	$r(F_k, F_2)$
...			...	...	...	...
F_i				$r(F_i, F_j)$	...	$r(F_k, F_j)$
...				...	...	...
F_k						1

When the linear correlation coefficients are grater then 0,5 between the variables there is a linear correlation and a model for estimating the effort is built:

$Effort = a_0+a_1*f_1+a_2*f_2+...+a_k*f_k$

In (Visoiu 2005, 94-100) the linear regression model generator is presented. The technology oversees the way in which from a set of generated models a small subset is selected, and after a severe filtering only one model is selected.

A specific structure is needed in such that the model is simple and representative.

4. Software structure used for building effort estimation models

The software product for effort estimation is built as an online software application and it is available at: www.estimaresarcinamaxima.somee.com

Now the software product is using as input a text file with the following structure:

M
K
$X_{11}, X_{12}, \ldots, X_{1k}$
$X_{21}, X_{22}, \ldots, X_{2k}$
...
$X_{m1}, X_{m2}, \ldots, X_{mk}$

where:

M – no. of persons
K – no. of variables
X_1 – dependant variable
$X_2, \ldots, X_k$ – independent variables

In the near future an interface will be defined such that users will input the data interactively.

The product computes the correlation coefficients between the independent variables.

Based on the correlation coefficients and the inputted options by the user the product develop effort estimation models.

Models like the following are generated:

Efort1= a1*Weight+b1
Effort2=a2*Age +b2
Effort3=a3*Height+b3
Effort4=a4*Weight+c4*Age+b4
Effort5=a5*Weight+c5*Height+b5
Effort6=a6*Age+c6*Height+b6
Effort7=a7*Weight+c7*Age+d7*Height+b7

For each the difference between the squares sum is computed like;

$$Dif = \sum_{j=1}^{N} abs(Effort(F_{ij}) - EffectiveEffort(j))$$

where N represents the number of elements in the collectivity.

The model is selected based on which one has the minimum square sum difference.

5. Maximum effort estimation for weight lifters

Data is collected regarding the results at the weight lifters trial at the Olympic Games in Beijing 2008, the results are given in table 2 (Appendix 1.).

The correlation coefficients are computed as shown in figure 1:

	X1	X2	X3	X4
X1	1	-0.0758218238303701	0.829045833400274	0.708383990616877
X2		1	0.0398851733925065	0.0398314524693218
X3			1	0.812910316100301
X4				1

Figure 1. Correlation coefficients matrix

The coefficients of the model which has as dependent variables X3 and X4 are computed. X2 is not considered because the correlation coefficient indicates a weak relation with the dependent variable. The resulting model is:

$$Y = 10.49757 + 1.144350*X3 + 0.295702*X4$$

By applying the created model to the data set an average error of 10.156 is obtained.

With the model:

M_1: Effort = 10.49757 + 1.144350*Weight + 0.295702*Height

other weight lifters H_{n+1}, H_{n+2} information is introduced in the model. The results of the model are compared with the real results obtained by the weight lifters in competitions as shown in Table 3.

Table 3. Comparation of estimated and effective results for a new dataset with heavier weightlifters

Weight	Height	Estimated result	Obtained result	Difference
145,93	183	231.606	203	28.61
124,13	187	207.842	210	-2.16
144,97	181	229.916	206	23.92
144,09	185	230.091	207	23.09
130,25	190	215.733	201	14.73
142,89	190	230.197	196	34.20
131,16	177	212.93	185	27.93
132,16	183	215.848	188	27.85
154,15	183	241.013	165	76.01
148,48	175	232.158	175	57.16
130,04	185	214.013	171	43.01
135,13	180	218.36	140	78.36

It is observed that the subset of weight lifters belonging to 105+ category increases the level of non-homogeneity of the collectivity, this requests they be processed separately. For them:

- the correlation matrix is given in Table 4
- the models that highlight the connections between effort and the weight lifters characteristics are generated using a linear generator.

Table 4. Correlation between results and factors considered for heavy weight lifters

	Result	Weight	Height
Result	1	-0,45645	0,504417
Weight		1	-0,29538
Height			1

The list of generated models is given below along with the performance expressed as the sum of squared differences between real and estimated values denoted as SS:

M2: Y=-193,6968 +0,0513 Weight +2,0400 Height SS :3969,9226
M3: Y=-181,4013tl +2,0117 Height SS:3972,2177
M4: Y=218,8667tl -0,2281Weight SS:4871,1639

where Y is the resultative variable as denoted in the output obtained from the generator.

Using the model with the least sum of squared differences, which includes the both factors, the values are estimated again and the results compared with the anterior model, as shown in table 5.

Table 5. Comparison between initial model and model built specially for heavy weight lifters

Effective results	Estimated results using M1	M1 differences	Estimated results using M2	M2 model differences
203	231.606	28.61	187,1094	-15,8906
210	207.842	-2.16	194,1511	-15,8489
206	229.916	23.92	182,9802	-23,0198
207	230.091	23.09	191,095	-15,905
201	215.733	14.73	200,585	-0,41497
196	230.197	34.20	201,2335	5,233457
185	212.93	27.93	174,1117	-10,8883
188	215.848	27.85	186,403	-1,59699
165	241.013	76.01	187,5311	22,5311
175	232.158	57.16	170,9202	-4,07978
185	214.013	43.01	166,1221	-18,8779
180	218,36	78.36	103,1051	-76,8949

It is observed that the medium difference using M2 is 17,59 which makes this second model more suitable for heavy weight lifters.

In order to study the stability of the model, the data set is divided in two groups. The first group contains the weight lifters with a height smaller or equal to 165 cm (165 = Hmin + (Hmax-Hmin)/2). The first group has 46 records, and the second one 64.

Generating models for the two sets the following results are obtained:

For the first group the generated model is:

M5: Result = -94.5945 + 1.040276*Weight + 0.992316*Height

For the second group the generated model is:

M6: Result = 153.3072 + 1.312025*Weight - 0.61078*Height

Estimations of the results of the athletes belonging to the first group are made using the generated model of the second set as shown in table 6 (Appendix 2).

The sum of the absolute values given by the differences between the real results and the estimated ones is 531.88, so the average result prediction error is 11.5626087 kg.

The average of real results is 131.9782609 and the average of estimated results is 141.0154348, the difference between them is 9.037173913.

Estimations are made for the second weight lifters group using the model generated by the first group as shown in table 7 (Appendix 3.).

The absolute value sum of the differences for the second data set is 771.99, so the result estimation is made with an average error of 12.06234375. The average of the real results is 161.0625 and the average of the estimated results is 167.3745781, the difference between the two is 6.312078125. The difference between the two averages is positive which means most of the athletes don't manage to lift the maximum weight that they should for their height and weight.

A new model is computed based on the existing ones to improve prediction quality. The coefficients of the new model are obtained as an arithmetic mean of the coefficients of the previous models.

The model for the first weight lifters group is:

M5: Result = -94.5945 + 1.040276*Weight + 0.992316*Height

The model for the second weight lifters group is:

M6: Result = 153.3072 + 1.312025*Weight - 0.61078*Height

The new model is:

M7: Result = 29.35635 + 1.1761505*Weight + 0.190768*Height

The new model tested using the initial data as shown in table 8 (Appendix 4.).

By applying the new model on the complete data set an average error of 10.33209091 is obtained, smaller than the arithmetic mean of the average error obtained in the two models built based on the two data sets which were equal to 11.81247622. The average of the results is 148.9, and the average of the estimated results with the new model is 152.626, the difference between them is 3.73.

This value is two times smaller then the average of the values computed for the first two models.

The model created based on the two previous models is better because it minimizes the error thus giving more precise estimations.

Comparing with the initial model on the full data set, this model is less efficient because the error average (10.33209091) is grater then the one of the initial model (10.159).

The capacity of an entity represents a maximum level of which the entity has the capability of reaching in normal evolution conditions. The maximum lifting effort is highlighted for a specialized category of athletes. If it is desired to translate to other typologies of specializations it is important to collect data related to the lifting effort orientated to maximum. Contrary, the maximum estimated level is error prone when a lot of persons in the collectivity succeed in accomplishing it. The maximum effort must be a desiderate, without the need of correcting it periodically.

For a person P outside the collectivity the maximum effort is estimated using the selected model. If person P is characterized by:

- age 25 years;
- weight 97Kg
- height 179cm

it results that by applying the model
M7: Result = 29.35635 + 1.1761505*Weight + 0.190768*Height
the maximum effort associated to person P is
Fmax = 177 Kg.

If person P unfolds a lifting process which has R lifting actions of weight of mass G1, G2,... G_R Kg, it results that in average P lifted G_{avg} Kg, meaning $(G_1+G_2+...+G_R)/R$ Kg obtained based on the relationship:

$G_{avg}=(G_1+G_2+...+G_R)/R$

In order to estimate the activity made it is necessary to compute:

- the relative effort given by

  $G_{rel} = G_{avg}/F_{max}$

- the maximum relative effort given by

  $G_{relmax} = max\{G_1G_2...G_K\}/F_{max}$

When performance structural modification occur at collectivity level it is necessary to recalculate the maximum effort such that G_{rel} and G_{relmax} must always be smaller then 1.

6. Conclusions

Human collectivities are suitable for extracting large datasets with a large number of records and a large number of variables.

The study of large datasets has advantages over studying only small samples and is aided by the new directions in recording, storing and processing data. Data is collected automatically, powerful databases store it and processing power is increasing every day. There is also a strong vector for distributed applications, distributed storage and distributed processing which improve such processes.

The developed models are stored in modelbases and are subject to reestimation, validation and refinement.

Development assumes:

- moving towards other domains;
- maximum effort for equipment, cars;
- including new variables.

Defining a maximum thereshold for the studied variables as the effort is in this article is important for comparison between activities. Accurate models include more significant independent variables from the dataset but exclude insignificant ones. This is achieved by model generation and refinement.

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Appendix 1.

Table 2. The results obtained by weight lifters and their description characteristics.

Weight lifer code	Result (kg) – X_1	Age (in years) – X_2	Weight (kg) – X_3	Height (cm) – X_4	Estimated result	Difference
H001	132	18	55.37	156	119.99	12.01
H002	130	23	55.97	152	119.494	10.51
H003	130	19	55.91	155	120.312	9.69
H004	128	21	55.85	157	120.835	7.17
H005	120	29	55.67	155	120.037	-0.04
H006	115	32	55.53	157	120.469	-5.47
H007	121	27	55.77	161	121.926	-0.93
H008	106	28	55.84	155	120.232	-14.23
H009	116	22	55.64	162	122.073	-6.07
H010	114	28	55.79	155	120.175	-6.17
H011	112	24	55.74	159	121.3	-9.30
H012	114	33	55.94	164	123.008	-9.01
H013	110	26	55.99	161	122.178	-12.18
H014	109	32	55.63	154	119.696	-10.70
H015	143	25	61.91	161	128.952	14.05
H016	138	28	61.47	163	129.04	8.96
H017	135	21	61.9	161	128.941	6.06
H018	130	18	61.66	161	128.666	1.33
H019	132	19	61.6	165	129.78	2.22
H020	132	24	61.75	157	127.586	4.41
H021	126	22	61.96	161	129.01	-3.01
H022	130	25	61.97	158	128.134	1.87
H023	128	25	61.95	163	129.589	-1.59
H024	120	30	61.69	145	123.969	-3.97
H025	115	31	61.67	160	128.382	-13.38
H026	158	21	68.97	168	139.101	18.90
H027	151	27	68.38	167	138.13	12.87
H028	148	30	68.92	162	137.27	10.73
H029	146	29	68.86	165	138.088	7.91
H030	146	30	68.64	158	135.767	10.23
H031	145	25	68.41	167	138.165	6.84
H032	147	24	68.99	164	137.941	9.06
H033	145	19	68.68	162	136.995	8.00
H034	135	27	68.76	168	138.861	-3.86
H035	135	20	68.85	166	138.373	-3.37
H036	139	27	68.23	165	137.367	1.63
H037	135	32	68.79	167	138.6	-3.60
H038	128	27	68.9	168	139.021	-11.02
H039	131	21	68.97	170	139.693	-8.69
H040	135	25	68.92	160	136.678	-1.68
H041	130	17	68.85	153	134.528	-4.53
H042	123	24	68.86	160	136.61	-13.61
H043	114	31	68.67	163	137.28	-23.28
H044	110	21	68.14	163	136.673	-26.67
H045	115	25	66.06	170	136.363	-21.36
H046	163	23	76.46	165	146.785	16.21
H047	168	28	76.91	168	148.187	19.81
H048	165	25	76.77	165	147.14	17.86
H049	155	26	76.86	165	147.243	7.76
H050	162	33	76.8	165	147.174	14.83
H051	157	25	76.53	163	146.274	10.73
H052	162	26	76.78	172	149.222	12.78
H053	161	24	76.71	167	147.663	13.34
H054	160	24	76.86	170	148.722	11.28
H055	157	20	76.56	172	148.97	8.03
H056	153	27	76.92	168	148.199	4.80
H057	154	20	76.52	165	146.854	7.15
H058	156	21	76.83	175	150.166	5.83
H059	143	27	75.83	160	144.586	-1.59
H060	144	26	76.24	168	147.421	-3.42
H061	140	22	76.9	164	146.993	-6.99
H062	140	20	76.69	175	150.006	-10.01
H063	140	24	76.93	180	151.759	-11.76
H064	145	28	76.38	171	148.468	-3.47
H065	130	25	76.57	167	147.503	-17.50
H066	135	23	76.98	172	149.45	-14.45
H067	124	29	76.15	178	150.275	-26.27
H068	110	23	75.53	175	148.678	-38.68
H069	180	22	84.41	172	157.953	22.05
H070	185	26	84.69	172	158.273	26.73
H071	177	25	83.78	175	158.119	18.88
H072	180	20	84.54	173	158.397	21.60
H073	169	26	84.84	174	159.036	9.96

H074	162	24	84.55	172	158.113	3.89
H075	165	25	84.71	174	158.888	6.11
H076	160	22	84.14	168	156.461	3.54
H077	166	23	84.52	170	157.487	8.51
H078	155	25	84.62	172	158.193	-3.19
H079	152	32	84.74	172	158.331	-6.33
H080	148	24	84.97	165	156.524	-8.52
H081	153	23	82.77	172	156.076	-3.08
H082	115	25	82.67	152	150.048	-35.05
H083	200	20	104.76	172	181.24	18.76
H084	193	25	104.72	182	184.152	8.85
H085	190	29	102.13	175	179.118	10.88
H086	182	23	102.48	179	180.701	1.30
H087	181	22	102.03	180	180.482	0.52
H088	184	31	104.27	181	183.341	0.66
H089	176	22	103.36	173	179.934	-3.93
H090	180	27	104.34	185	184.604	-4.60
H091	177	22	104.64	181	183.764	-6.76
H092	170	24	104.9	170	180.809	-10.81
H093	166	33	104.39	176	182	-16.00
H094	163	33	104.64	182	184.06	-21.06
H095	150	24	103.76	175	180.983	-30.98
H096	150	31	104.45	180	183.251	-33.25
H097	180	20	93.64	175	169.402	10.60
H098	185	23	92.99	178	169.546	15.45
H099	176	21	93.69	176	169.755	6.24
H100	181	27	93.83	170	168.141	12.86
H101	178	28	92.3	178	168.756	9.24
H102	180	26	92.32	170	166.413	13.59
H103	175	25	93.9	177	170.291	4.71
H104	173	24	93.74	175	169.517	3.48
H105	173	27	93.09	172	167.886	5.11
H106	170	21	93.97	176	170.076	-0.08
H107	168	36	93.69	179	170.642	-2.64
H108	170	27	93.71	176	169.778	0.22
H109	160	27	93.01	172	167.794	-7.79
H110	155	21	93.9	168	167.63	-12.63

Appendix 2.

Table 6. Estimation for first group using M6

Weight lifter code	Result	Age	Weight	Height	Estimated result	Difference
H001	120	30	61.69	145	145.683	-25.68
H002	130	23	55.97	152	133.903	-3.90
H003	115	25	82.67	152	168.934	-53.93
H004	130	17	68.85	153	150.191	-20.19
H005	109	32	55.63	154	132.235	-23.24
H006	130	19	55.91	155	131.992	-1.99
H007	120	29	55.67	155	131.677	-11.68
H008	106	28	55.84	155	131.9	-25.90
H009	114	28	55.79	155	131.834	-17.83
H010	132	18	55.37	156	130.672	1.33
H011	128	21	55.85	157	130.691	-2.69
H012	115	32	55.53	157	130.271	-15.27
H013	132	24	61.75	157	138.432	-6.43
H014	130	25	61.97	158	138.11	-8.11
H015	146	30	68.64	158	146.861	-0.86
H016	112	24	55.74	159	129.325	-17.33
H017	115	31	61.67	160	136.495	-21.49
H018	135	25	68.92	160	146.007	-11.01
H019	123	24	68.86	160	145.928	-22.93
H020	143	27	75.83	160	155.073	-12.07
H021	121	27	55.77	161	128.143	-7.14
H022	110	26	55.99	161	128.432	-18.43
H023	143	25	61.91	161	136.199	6.80
H024	135	21	61.9	161	136.186	-1.19
H025	130	18	61.66	161	135.871	-5.87
H026	126	22	61.96	161	136.265	-10.26
H027	116	22	55.64	162	127.362	-11.36
H028	148	30	68.92	162	144.786	3.21
H029	145	19	68.68	162	144.471	0.53
H030	138	28	61.47	163	134.4	3.60

H031	128	25	61.95	163	135.03	-7.03
H032	114	31	68.67	163	143.847	-29.85
H033	110	21	68.14	163	143.151	-33.15
H034	157	25	76.53	163	154.159	2.84
H035	114	33	55.94	164	126.534	-12.53
H036	147	24	68.99	164	143.656	3.34s
H037	140	22	76.9	164	154.034	-14.03
H038	132	19	61.6	165	133.349	-1.35
H039	146	29	68.86	165	142.875	3.13
H040	139	27	68.23	165	142.048	-3.05
H041	163	23	76.46	165	152.846	10.15
H042	165	25	76.77	165	153.253	11.75
H043	155	26	76.86	165	153.371	1.63
H044	162	33	76.8	165	153.292	8.71
H045	154	20	76.52	165	152.925	1.08
H046	148	24	84.97	165	164.011	-16.01

Appendix 3.

Table 7. Estimation for second group using M5

Weight lifter code	Result	Age	Weight	Height	Estimated result	Difference
H001	135	20	68.85	166	141.753	-6.75
H002	151	27	68.38	167	142.256	8.74
H003	145	25	68.41	167	142.288	2.71
H004	135	32	68.79	167	142.683	-7.68
H005	161	24	76.71	167	150.922	10.08
H006	130	25	76.57	167	150.776	-20.78
H007	158	21	68.97	168	143.862	14.14
H008	135	27	68.76	168	143.644	-8.64
H009	128	27	68.9	168	143.79	-15.79
H010	168	28	76.91	168	152.122	15.88
H011	153	27	76.92	168	152.133	0.87
H012	144	26	76.24	168	151.425	-7.43
H013	160	22	84.14	168	159.643	0.36
H014	155	21	93.9	168	169.797	-14.80
H015	131	21	68.97	170	145.847	-14.85
H016	115	25	66.06	170	142.82	-27.82
H017	160	24	76.86	170	154.055	5.95
H018	166	23	84.52	170	162.023	3.98
H019	170	24	104.9	170	183.224	-13.22
H020	181	27	93.83	170	171.708	9.29
H021	180	26	92.32	170	170.138	9.86
H022	145	28	76.38	171	154.548	-9.55
H023	162	26	76.78	172	155.956	6.04
H024	157	20	76.56	172	155.727	1.27
H025	135	23	76.98	172	156.164	-21.16
H026	180	22	84.41	172	163.894	16.11
H027	185	26	84.69	172	164.185	20.82
H028	162	24	84.55	172	164.039	-2.04
H029	155	25	84.62	172	164.112	-9.11
H030	152	32	84.74	172	164.237	-12.24
H031	153	23	82.77	172	162.187	-9.19
H032	200	20	104.76	172	185.063	14.94
H033	173	27	93.09	172	172.923	0.08
H034	160	27	93.01	172	172.84	-12.84
H035	180	20	84.54	173	165.021	14.98
H036	176	22	103.36	173	184.599	-8.60
H037	169	26	84.84	174	166.325	2.67
H038	165	25	84.71	174	166.19	-1.19
H039	156	21	76.83	175	158.985	-2.99
H040	140	20	76.69	175	158.84	-18.84
H041	110	23	75.53	175	157.633	-47.63
H042	177	25	83.78	175	166.215	10.78
H043	190	29	102.13	175	185.304	4.70
H044	150	24	103.76	175	187	-37.00
H045	180	20	93.64	175	176.472	3.53
H046	173	24	93.74	175	176.576	-3.58
H047	166	33	104.39	176	188.648	-22.65
H048	176	21	93.69	176	177.517	-1.52
H049	170	21	93.97	176	177.808	-7.81
H050	170	27	93.71	176	177.537	-7.54
H051	175	25	93.9	177	178.727	-3.73
H052	124	29	76.15	178	161.255	-37.25
H053	185	23	92.99	178	178.773	6.23

H054	178	28	92.3	178	178.055	-0.06
H055	182	23	102.48	179	189.638	-7.64
H056	168	36	93.69	179	180.494	-12.49
H057	140	24	76.93	180	164.051	-24.05
H058	181	22	102.03	180	190.162	-9.16
H059	150	31	104.45	180	192.679	-42.68
H060	184	31	104.27	181	193.484	-9.48
H061	177	22	104.64	181	193.869	-16.87
H062	193	25	104.72	182	194.945	-1.94
H063	163	33	104.64	182	194.861	-31.86
H064	180	27	104.34	185	197.526	-17.53

Appendix 4.

Table 8. Estimations using M7 model

Weight lifter code	Result	Age	Weight	Height	Estimated result	Difference
H001	120	30	61.69	145	129.574	-9.57
H002	130	23	55.97	152	124.182	5.82
H003	115	25	82.67	152	155.585	-40.59
H004	130	17	68.85	153	139.522	-9.52
H005	109	32	55.63	154	124.164	-15.16
H006	130	19	55.91	155	124.684	5.32
H007	120	29	55.67	155	124.402	-4.40
H008	106	28	55.84	155	124.602	-18.60
H009	114	28	55.79	155	124.543	-10.54
H010	132	18	55.37	156	124.24	7.76
H011	128	21	55.85	157	124.995	3.01
H012	115	32	55.53	157	124.619	-9.62
H013	132	24	61.75	157	131.934	0.07
H014	130	25	61.97	158	132.384	-2.38
H015	146	30	68.64	158	140.229	5.77
H016	112	24	55.74	159	125.247	-13.25
H017	115	31	61.67	160	132.412	-17.41
H018	135	25	68.92	160	140.94	-5.94
H019	123	24	68.86	160	140.869	-17.87
H020	143	27	75.83	160	149.067	-6.07
H021	121	27	55.77	161	125.664	-4.66
H022	110	26	55.99	161	125.923	-15.92
H023	143	25	61.91	161	132.885	10.11
H024	135	21	61.9	161	132.874	2.13
H025	130	18	61.66	161	132.591	-2.59
H026	126	22	61.96	161	132.944	-6.94
H027	116	22	55.64	162	125.702	-9.70
H028	148	30	68.92	162	141.321	6.68
H029	145	19	68.68	162	141.039	3.96
H030	138	28	61.47	163	132.75	5.25
H031	128	25	61.95	163	133.314	-5.31
H032	114	31	68.67	163	141.218	-27.22
H033	110	21	68.14	163	140.594	-30.59
H034	157	25	76.53	163	150.462	6.54
H035	114	33	55.94	164	126.436	-12.44
H036	147	24	68.99	164	141.785	5.22
H037	140	22	76.9	164	151.088	-11.09
H038	132	19	61.6	165	133.284	-1.28
H039	146	29	68.86	165	141.823	4.18
H040	139	27	68.23	165	141.082	-2.08
H041	163	23	76.46	165	150.762	12.24
H042	165	25	76.77	165	151.126	13.87
H043	155	26	76.86	165	151.232	3.77
H044	162	33	76.8	165	151.161	10.84
H045	154	20	76.52	165	150.832	3.17
H046	148	24	84.97	165	160.771	-12.77
H047	135	20	68.85	166	142.002	-7.00
H048	151	27	68.38	167	141.64	9.36
H049	145	25	68.41	167	141.675	3.32
H050	135	32	68.79	167	142.122	-7.12
H051	161	24	76.71	167	151.437	9.56
H052	130	25	76.57	167	151.272	-21.27
H053	158	21	68.97	168	142.524	15.48
H054	135	27	68.76	168	142.277	-7.28
H055	128	27	68.9	168	142.442	-14.44
H056	168	28	76.91	168	151.863	16.14
H057	153	27	76.92	168	151.875	1.13

H058	144	26	76.24	168	151.075	-7.08
H059	160	22	84.14	168	160.367	-0.37
H060	155	21	93.9	168	171.846	-16.85
H061	131	21	68.97	170	142.906	-11.91
H062	115	25	66.06	170	139.483	-24.48
H063	160	24	76.86	170	152.186	7.81
H064	166	23	84.52	170	161.195	4.80
H065	170	24	104.9	170	185.165	-15.17
H066	181	27	93.83	170	172.145	8.85
H067	180	26	92.32	170	170.369	9.63
H068	145	28	76.38	171	151.812	-6.81
H069	162	26	76.78	172	152.473	9.53
H070	157	20	76.56	172	152.215	4.79
H071	135	23	76.98	172	152.709	-17.71
H072	180	22	84.41	172	161.447	18.55
H073	185	26	84.69	172	161.777	23.22
H074	162	24	84.55	172	161.612	0.39
H075	155	25	84.62	172	161.694	-6.69
H076	152	32	84.74	172	161.835	-9.84
H077	153	23	82.77	172	159.518	-6.52
H078	200	20	104.76	172	185.382	14.62
H079	173	27	93.09	172	171.656	1.34
H080	160	27	93.01	172	171.562	-11.56
H081	180	20	84.54	173	161.791	18.21
H082	176	22	103.36	173	183.926	-7.93
H083	169	26	84.84	174	162.335	6.67
H084	165	25	84.71	174	162.182	2.82
H085	156	21	76.83	175	153.104	2.90
H086	140	20	76.69	175	152.94	-12.94
H087	110	23	75.53	175	151.575	-41.58
H088	177	25	83.78	175	161.279	15.72
H089	190	29	102.13	175	182.861	7.14
H090	150	24	103.76	175	184.778	-34.78
H091	180	20	93.64	175	172.875	7.12
H092	173	24	93.74	175	172.993	0.01
H093	166	33	104.39	176	185.71	-19.71
H094	176	21	93.69	176	173.125	2.87
H095	170	21	93.97	176	173.454	-3.45
H096	170	27	93.71	176	173.149	-3.15
H097	175	25	93.9	177	173.563	1.44
H098	124	29	76.15	178	152.877	-28.88
H099	185	23	92.99	178	172.683	12.32
H100	178	28	92.3	178	171.872	6.13
H101	182	23	102.48	179	184.036	-2.04
H102	168	36	93.69	179	173.697	-5.70
H103	140	24	76.93	180	154.176	-14.18
H104	181	22	102.03	180	183.697	-2.70
H105	150	31	104.45	180	186.544	-36.54
H106	184	31	104.27	181	186.523	-2.52
H107	177	22	104.64	181	186.958	-9.96
H108	193	25	104.72	182	187.243	5.76
H109	163	33	104.64	182	187.149	-24.15
H110	180	27	104.34	185	187.368	-7.37

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