The Journal of Strength and Conditioning Research™

Evaluation of Training Load During Suspension Exercise

Giuseppe Francesco Giancotti,[1] Andrea Fusco,[1,2] Carlo Varalda,[3] Giovanni Capelli,[1] and Cristina Cortis[1]

[1]Department of Human Sciences, Society and Health, University of Cassino and Lazio Meridionale, Cassino, Italy; [2]Department of Sports Science and Kinesiology, University of Salzburg, Salzburg, Austria; and [3]Italian Weightlifting Federation FIPE, Rome, Italy

Abstract

Giancotti, GF, Fusco, A, Varalda, C, Capelli, G, and Cortis, C. Evaluation of training load during suspension exercise. *J Strength Cond Res* 35(8): 2151–2157, 2021—The aims of this study were to evaluate body inclination and ground reaction force and to predict equations to estimate the training load distribution during suspension training (ST) static back-row at different lengths of the straps. Thirty volunteers (men = 16 and women = 14; age = 23.3 ± 1.7 years; body mass = 63.9 ± 13.3 kg; height = 167.9 ± 9.2 cm; body mass index [BMI] = 22.5 ± 3.4 kg·m^{-2}) performed 14 static back-rows at 7 different lengths of the straps in 2 different elbow positions (flexed and extended). When the length of the straps increased, ground reaction force and body inclination decreased. Moreover, in the flexed elbow position, higher ground reaction force values were recorded with respect to the extended one. Two multilevel regression models ($p < 0.05$) were created. In the first one, ground reaction force was used as a dependent variable, whereas body inclination angle, body mass, height, BMI, and elbow position were used as independent variables. Significant ($p < 0.05$) effects were found for all variables included in the model, with an intraclass correlation coefficient (ICC) of 0.31. In the second model, the body inclination angle was replaced by the length of the ST device. Significant ($p < 0.05$) effects were found also in the second model for all variables included, with an ICC of 0.37. The proposed models could provide different methods to quantify the training load distribution, even if the use of the straps' length could result easier and faster than body inclination angle, helping practitioners and instructors to personalize the workout to reach specific purposes and provide load progression.

Key Words: body mass, instability, back-row, resistance training, biomechanical characteristics

Introduction

Body mass resistance training is a widespread and inexpensive way to exercise effectively. The addition of instability to traditional body mass resistance exercises has become a common method for increasing sport specificity (1), promoting high level of functional health and performance benefits (4,5,20). Among these activities, suspension training (ST) became very popular. The unstable nature of ST enhances neuromuscular adaptations and training specificity, while providing varied and effective stimulus to increase performances (5,7–9,12,18,20,26).

When prescribing resistance training, improvements are achieved by applying appropriate guidelines (3) and the progressive overload principle, by increasing frequency or duration or both, varying movement velocity, recovery times, or adding weights and increasing volume (16). Using barbells, dumbbells, weight plates, and machines, the training load can be easily calculated as the percentage of the maximum repetition. However, ST device is composed of 1 or more straps connected to 1 or more anchor point(s) above the exerciser to which the user is suspended from the handles by either his or her hands or feet (2,17), whereas the nonsuspended pair of extremities are in contact with the ground (15). Therefore, during ST, it is difficult to establish adequate exercise prescription guidelines and apply the principle of progressive overload. Because during ST, the exercise intensity could depend on multiple factors, such as the degree of instability caused by the apparatus and the body position (22), the quantification of the training load might be challenging (11,13,14).

Nevertheless, only few studies (13,14,23), mainly focusing on pushing and pulling exercises, investigated the influence of these factors on training load and its distribution between upper and lower body during ST exercises. In particular, assessing and comparing the load applied on the ST device and the ground reaction forces during push-up at different angle inclinations, the load on the ST device increased when ST angle decreased and during elbow flexion with respect to elbow extension (14). Moreover, evaluating the load distribution between upper and lower body during ST push-up at different length of the straps, the load distribution has been reported to change when modifying the body inclination and the length of the ST device (13).

Although it is a widely used, pulling, closed kinetic chain exercise, only a few studies investigated the ST back-row (10,15,23,24,27–29), reporting greater muscle activation of the obliques, rectus abdominis, and middle and posterior deltoids than traditional back-row (15,29). However, to the best of our knowledge, only 1 study (23) investigated the relationship between body position and load distribution during ST back-row, showing that the load on the ST device was directly proportional to body inclination and indirectly proportional to the distance of the feet from the vertical hanging point (i.e., higher load values on the straps were recorded in the horizontal positions and when the feet position was closer to vertical hanging point). In their study, Melrose and Dawes (23) used different body inclinations and distances from the hanging point to predict 4 equations to estimate the load on the straps at the 4 measured angles. However, measuring angles while exercising could not always be feasible, as

Address correspondence to Dr. Cristina Cortis, c.cortis@unicas.it

Journal of Strength and Conditioning Research 35(8)/2151–2157

in practical settings, easier and faster methods are favored. Conversely, the length of the straps could be easier and faster to determine with respect to the angle measurement. Therefore, the aims of this study were (a) to evaluate body inclination and ground reaction force and (b) to predict equations to estimate the training load distribution during ST static back-row at different lengths of the straps. It was hypothesized that the training load could change when modifying the length of the ST device while maintaining the feet position fixed.

Methods

Experimental Approach to the Problem

Three principles are the fundamental characteristics of the ST concept: vector-resistance, stability, and pendulum (6). The vector-resistance principle gives the possibility to adjust the resistance by changing the angle (i.e., the higher body inclination angle with respect to the ground, the easier the exercise). The stability principle regards the base of support and balance, where the unstable base of support can change the muscles recruitment during this type of activity by implementing the difficulty and intensity of several exercises (i.e., bigger support base is, the easier an exercise will be). The pendulum principle deals with the starting position in relation to the anchor point (i.e., lower inclination of ST device with respect to its vertical is, the easier the exercise will be). According to those principles, the training load is affected by different factors, such as the length of the straps, the body inclination angle, the feet position, and their interaction. Although these variables could affect the training load, only a few studies investigated the biomechanical characteristics of ST by taking into consideration these parameters (13,14,23), whereas to the best of our knowledge, no study investigated the effect of the length of the suspension straps on training load during ST back-row. Therefore, this study was conducted to evaluate body inclination and ground reaction force during ST static back-row at different lengths of the straps (148, 158, 168, 178, 188, 198, and 208 cm) and different elbow positions (flexed and extended), and to predict equations to estimate the training load distribution between upper and lower body. Although ST exercises are usually performed dynamically, a static exercise was proposed to better control and standardize the experimental protocol and to avoid any influence as a result of physical fitness or speed of movement or both that could increase variability during the measurements.

A force platform (range from 0 to 10,000 N; linearity $<\pm 0.5\%$ Full Scale Output) was used to evaluate the ground reaction force, whereas motion analysis software was used to evaluate the body inclination angle with respect to the horizontal surface. The force platform showed (13) high intraclass correlation coefficients (ICCs = 0.97; 95% confidence interval, 0.95–0.99). To predict the training load distribution, different formulas were extrapolated from 2 multilevel regression models. Ground reaction force was used as a dependent variable, whereas body inclination (replaced by the length of the ST device in the second model), body mass, height, body mass index (BMI), and elbow position were used as independent variables.

Subjects

Thirty physically active (engaging in at least 3 $d\cdot wk^{-1}$ of moderate-to-intense physical activity) volunteers were recruited for the study (conducted from March 2016 to April 2016). Subjects (aged 22–27 years old) were included if they had at least 1 year of ST experience and were excluded if they reported any preexisting condition, such as physical injury or musculoskeletal disorders. They were required to refrain from any moderate-to-vigorous physical activity for at least 24 hours and to abstain from food, drink, and stimulant consumption for at least 4 hours before the experimental session. Before the test, written informed consent was obtained from all subjects, and they were informed of the procedures of the test. The study was approved by the Department of Human Sciences, Society and Health of the University of Cassino and Lazio Meridionale and was performed in accordance with the Declaration of Helsinki for Human Research of 1964 (last modified in 2000). All descriptive characteristics of the subjects are reported in Table 1.

Procedures

Before starting the experimental sessions, body mass was measured through a force plate (Kistler Quattro Jump 9290AD; Kistler, Winterthur, Switzerland), whereas height was measured using a stadiometer (Seca, model 709; Vogel & Halke, Hamburg, Germany).

After a 10-minute specific warm-up including dynamic and static ST back-row, subjects were asked to perform 14 static ST back-row (holding the position for 5 seconds) at 7 different lengths of ST device (148, 158, 168, 178, 188, 198, and 208 cm; Figure 1) ranging from the simplest to the most challenging, in 2 different elbow (flexed and extended) positions (Figure 2).

An ST device (AINS Suspension Training FIPE, Rome, Italy) was anchored at 2.65 m above the force platform. Subjects stood barefoot on the force plate, with their feet shoulder width apart positioned under the anchored point and visual reflective markers were applied to subjects' left lateral malleolus and at the acromion process.

During the experimental sessions, the force platform was used to evaluate the ground reaction force, whereas a video camera (Sony Camcorder HDR-CX290/B; Sony, Minato, Tokyo, Japan) fixed at 4.50 m from the subjects and 0.90 m above the ground was used to record all the trials. The recorded videos were then imported on a motion analysis software (Dartfish Team Pro 5.5; Dartfish, Fribourg, Switzerland) and analyzed to calculate the body inclination angle (line passing through the 2 visual reflective markers) with respect to the horizontal plane.

Statistical Analyses

Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA) and Stata statistical software version 14.1 (StataCorp, College Station, TX) were used for statistical analysis. Means and *SD*s for all descriptive characteristics of the subjects were calculated.

Mean value for all data recorded by force plate was calculated and then normalized in relation to body mass using the following formula:

Table 1
Mean and *SD* of subject descriptive characteristics.*

	Women ($n = 14$)	Men ($n = 16$)	Total ($n = 30$)
Age (y)	23.0 ± 1.7	23.6 ± 1.7	23.3 ± 1.7
Body mass (kg)	53.7 ± 8.8	72.8 ± 9.7	63.9 ± 13.3
Height (cm)	160.5 ± 5.6	174.4 ± 6.2	167.9 ± 9.2
BMI ($kg\cdot m^{-2}$)	20.8 ± 2.7	24.0 ± 3.4	22.5 ± 3.4

*BMI = body mass index.

Figure 1. Back-row at different lengths of suspension training device.

$$\text{Load (\%body mass)} = \text{load(kg)}\cdot\text{body mass}^{-1}\cdot 100.$$

Multilevel regression models (or hierarchical linear model, (25)) were created to predict models to estimate the training load distribution. Statistical significance (p) was set at 0.05.

Results

Results showed that when body inclination angle increased, the ground reaction force increased (Table 2). In particular, body inclination angles were indirectly proportional to the length of the ST device (Figure 3).

Ground reaction forces in relation to the position are shown in Figure 4. When the length of the ST straps increased, the ground reaction force decreased. Moreover, lower values on the force plate were recorded with extended elbow with respect to flexed ones.

Two multilevel regression models were created. In the first one, ground reaction force was used as a dependent variable, whereas body inclination angle, body mass, height, BMI, and elbow position (extended elbow = 0; flexed elbow = 1) were used as independent variables. Significant ($p < 0.05$) effects were found for all variables included in the model, with an ICC of 0.31. Analyzing the model (Table 3), the following equation to estimate the ground reaction force was extrapolated:

$$\begin{aligned}\text{Load} = {} & -132.9134 + 0.3724671\cdot\text{angle} \\ & - 1.299028\cdot\text{body mass} + 0.9844512\cdot\text{height} \\ & + 3.675008\cdot\text{BMI} - 2.073684\cdot\text{elbow}.\end{aligned}$$

With the inverse formula, the equations to predict the body inclination angles to train to the known ground reaction force were created:

$$\begin{aligned}\text{Angle}_{\text{extension}} = {} & (\text{load}_{\text{extension}} + 132.9134 \\ & + 1.299028\cdot\text{body mass} - 0.9844512\cdot\text{height} \\ & - 3.675008\cdot\text{BMI})/0.3724671.\end{aligned}$$

$$\begin{aligned}\text{Angle}_{\text{flexion}} = {} & (\text{load}_{\text{flexion}} + 134.987084 \\ & + 1.299028\cdot\text{body mass} - 0.9844512\cdot\text{height} \\ & - 3.675008\cdot\text{BMI})/0.3724671.\end{aligned}$$

In the second model (Table 4), the body inclination angle was replaced by the length of the ST device. Significant ($p < 0.05$) effects were also found in this model for all the variables included, with an ICC of 0.37. By analyzing this model, the following equation to estimate the ground reaction force knowing the length of the straps was extrapolated:

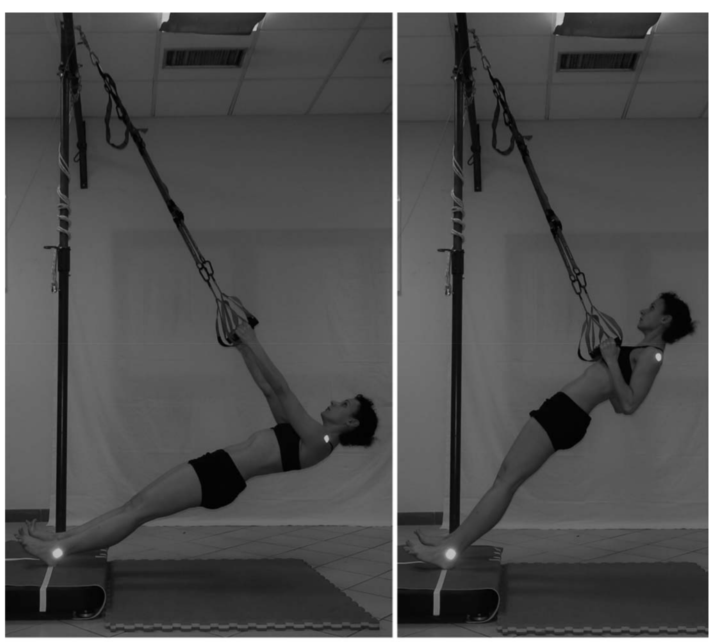

Figure 2. Suspension training back-row at different elbow positions.

Table 2

Mean and *SD* of body inclination angles and ground reaction force expressed as percentage of body mass at different lengths of suspension training device.

	Extended elbow		Flexed elbow	
Length (cm)	Angle (°)	Ground reaction force (%)	Angle (°)	Ground reaction force (%)
148	36.2 ± 2.9	47.1 ± 1.6	58.5 ± 4.8	49.5 ± 3.8
158	31.4 ± 2.9	44.7 ± 2.3	52.4 ± 4.6	49.0 ± 3.4
168	26.5 ± 2.3	42.8 ± 1.7	45.9 ± 5.0	47.6 ± 2.7
178	21.4 ± 2.5	39.9 ± 2.4	39.8 ± 6.2	46.3 ± 2.7
188	16.5 ± 2.7	37.8 ± 2.5	35.0 ± 4.9	43.8 ± 2.8
198	10.8 ± 2.9	34.2 ± 2.5	29.1 ± 4.8	40.8 ± 2.1
208	5.6 ± 3.9	31.9 ± 2.8	22.8 ± 5.6	38.1 ± 2.7

$$\begin{aligned}\text{Load} = {} & -69.80267 - 0.2199257\cdot\text{length} \\ & - 1.281452\cdot\text{body mass} + 0.8883487\cdot\text{height} \\ & + 3.624841\cdot\text{BMI} + 5.188559\cdot\text{elbow}.\end{aligned}$$

By means of opposite formula, it is possible to estimate the length of the ST device knowing the ground reaction force:

$$\begin{aligned}\text{Length}_{\text{extension}} = {} & (\text{Load}_{\text{extension}} + 69.80267 \\ & + 1.281452\cdot\text{body mass} - 0.8883487\cdot\text{height} \\ & - 3.624841\cdot\text{BMI})/-0.2199257.\end{aligned}$$

Finally, by keeping constant the length of the ST device, it is possible to calculate the ground reaction force difference between flexed and extended elbow:

$$\text{Load}_{\text{flexion}} = \text{load}_{\text{extension}} + 5.188559.$$

Discussion

The aims of this study were (a) to evaluate body inclination and ground reaction force and (b) to predict equations to estimate the training load distribution during ST static back-row at different lengths of the straps. In line with the vector-resistance principle, the main results showed that when increasing the length of the straps, the ground reaction force decreased and the body angle inclination with respect to the floor decreased, confirming the hypothesis of this study.

In line with recent researches (13,14,23), findings from this study confirm the relation between load distribution and body inclination. Despite that a different ST exercise was evaluated (i.e., pulling vs. pushing exercise), similar findings were found during ST push-up (13). To the best of our knowledge, only 1 study (13) evaluated the variation in load distribution based on the changes in the length of the straps, highlighting that when increasing the length of the ST device, the ground reaction force decreased and the load on the straps increased when performing ST push-up. Those findings are in line with the present study, when the lowest ground reaction force was found with the ST device at 208 cm in either flexed or extended elbow position.

Although in this study higher ground reaction force was found during ST back-row with flexed elbow when compared with extended elbow, an inverse trend was found by Giancotti et al. (13) because of the differences between exercises. By considering that back-row is a pulling exercise and push-up a pushing exercise, changing from an extended to a flexed elbow position lead to an increase in body inclination during ST back-row, whereas the same change during ST push-up lead to a decrease in body inclination.

In this study, 2 different multilevel regression models were created to evaluate the training load distribution during ST back-row using ground reaction force as a dependent variable and body

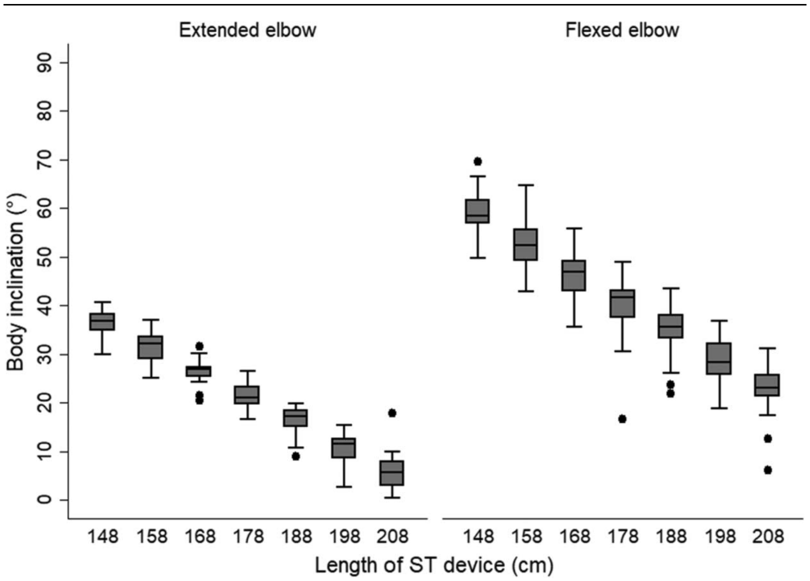

Figure 3. Box plot of body inclination in relation to length of suspension training (ST) device during back-row with extended and flexed elbow positions.

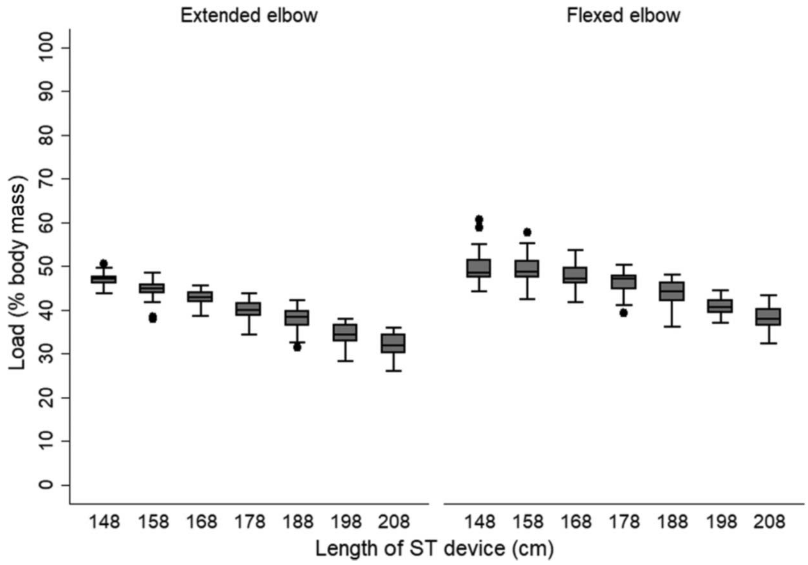

Figure 4. Box plot of ground reaction force in relation to length of suspension training (ST) device during back-row with extended and flexed elbow positions.

inclination angle or length of the ST device, body mass, height, BMI, and elbow position as independent variables. In the first model, which took into consideration the body inclination angle, an ICC of 0.31 was found, suggesting that 31% of the outcome variability (ground reaction force) depends on differences among individuals, whereas the remaining 69% depends on differences between the measurements made in the same individual. Using the formula extrapolated from the model, it is possible to estimate the training load distribution by knowing the subjects' anthropometrical characteristics and body inclination angle. Furthermore, through opposite equations, it is possible to predict the body inclination angle to train at a known training load. Although these results are unique and essential for coaches, the equations extrapolated in this study present some limitations. In fact, when changing from extended to flexed elbow (or vice versa), the joint position and the body inclination angle change, and consequently, these factors could influence the load. Moreover, it is difficult to evaluate the body inclination during ST exercises because a goniometer would be needed. For this reason, in the second model (ICC = 0.37), the body inclination angle was replaced by the length of ST the device, to create an equation to estimate the load by knowing the length of the straps or estimate the length of the ST device to use a known training load. By maintaining the length of the ST device constant during the exercise, the ground reaction force difference between extended and flexed elbow is of 5.19% of body mass.

In the present study, ST back-row was evaluated only during static positions. However, by evaluating the extended and flexed elbow static positions, the extrapolated formulas will allow the estimation of a minimum-maximum range of load distribution comprehensive of all the positions included in a dynamic ST back-row. Although the multilevel regression analysis permits to overcome the limitation of missing data, because the ST back-row was evaluated only with the feet positioned under the anchored point, some subjects were not able to complete the experimental protocol with the longest length of the ST device because of the lack of grip between feet and the force plate surface. Consequently, changing the feet position while keeping equal the length of the ST device, body inclination angle would be different, possibly affecting the training load distribution. Probably, the exercises with ST straps of longer length could be replaced by exercises with straps of shorter length with different feet position distance from the anchored point, allowing the exerciser being more comfortable and able to train with higher load on the straps, according to the pendulum principle (6). Therefore, further studies are needed to predict equations to be used in ST back-row performed with different feet position and distance from the anchored point, as well as for other ST exercises.

Table 3

Multi-level regression model between dependent variable (load on the force plate normalized in relation to body mass) and independent variables (body inclination angle, body mass, height, BMI, and elbow position).*

Load	Coef.	SE	*z*	*p* > |z|	95% CI
Angle	0.3724671	0.0104168	35.76	0.000	0.3520505 to 0.3928837
Body mass	−1.299028	0.5695359	−2.28	0.023	−2.415298 to −0.182758
Height	0.9844512	0.4120159	2.39	0.017	0.1769148 to 1.791988
BMI	3.675008	1.624977	2.26	0.024	0.4901119 to 6.859904
Elbow	−2.073684	0.3069032	−6.76	0.000	−2.675203 to −1.472165
_cons	−132.9134	69.25204	−1.92	0.055	−268.6449 to 2.818098

*SE = standard error; CI = confidence interval; angle = body inclination angle; BMI = body mass index; elbow = elbow position (elbow in extension = 0; elbow in flexion = 1); _cons = intercept; coef. = coefficient.

Journal of Strength and Conditioning Research™

Table 4

Multilevel regression model between dependent variable (ground reaction force normalized in relation to body mass) and independent variables (length of suspension training device in centimeters, body mass, height, BMI, and elbow position).*

Load	Coef.	SE	z	p > |z|	95% CI
Length	−0.2199257	0.0053827	−40.86	0.000	−0.2304757 to −0.2093758
Body mass	−1.281452	0.5727453	−2.24	0.025	−2.404012 to −0.1588914
Height	0.8883487	0.4144022	2.14	0.032	0.0761353 to 1.700562
BMI	3.624841	1.634237	2.22	0.027	0.4217946 to 6.827887
Elbow	5.188559	0.2095673	24.76	0.000	4.777815 to 5.599303
_cons	−69.80267	69.68168	−1.00	0.316	−206.3762 to 66.7709

*BMI = body mass index; coef. = coefficient; SE = standard error; CI = confidence interval; elbow = elbow position (elbow in extension = 0; elbow in flexion = 1); _cons = intercept.

Practical Applications

The results of this study suggest that during ST back-row, the ground reaction force decreased when the length of the ST device increased. Furthermore, by increasing the body inclination angle with respect to the floor, the ground reaction force increased, and, consequently, when the length of the straps increased, the body inclination angle decreased. In addition, when changing from an extended to a flexed elbow position, the body inclination angle increases and consequently the ground reaction force increases.

The predicted equations allow to estimate the training load distribution, by knowing the anthropometric characteristics of the users and the body inclination angle or the length of the ST device. On the other hand, by knowing the anthropometric characteristics of the users and the training load, the body inclination angle or the length of the ST device could be estimated.

From a practical point of view, if a subject with a body mass of 65 kg and a height of 170 cm (and consequently a BMI of 22.5 kg·m^{-2}) wants to train with a length of the ST device of 170 cm, using the predicted formula

$$(\text{Load} = -69.80267 - 0.2199257\cdot\text{length} - 1.281452\cdot\text{body mass} + 0.8883487\cdot\text{height} + 3.624841\cdot\text{BMI} + 5.188559\cdot\text{elbow}),$$

it is possible to estimate that he or she would exert a contact force on the ground of 42.1% of the body mass (corresponding to 27.4 kg) during extension and of 47.3% of the body mass (corresponding to 30.7 kg) during flexion. Therefore, with a length of the straps of 170 cm during ST back-row, this subject would distribute from a minimum of 34.3 kg to a maximum of 37.6 kg load on the upper body.

Even though the forces in the upper limbs were not directly evaluated in the present study, it could be assumed that the upper-body load distribution during the flexed and the extended position (by keeping the other independent variables constant) could indirectly reflect the forces exerted by the upper body and limbs. Therefore, if the same subject wants to train with a maximum load on the upper body of 35 kg and loading the lower body with 30 kg (corresponding to 46.1% body mass), by applying the predicted formula

$$(\text{Length}_{\text{extension}} = [\text{load}_{\text{extension}} + 69.80267 + 1.281452\cdot\text{body mass} - 0.8883487\cdot\text{height} - 3.624841\cdot\text{BMI}]/-0.2199257).$$

the length of the straps should be set at 151.6 cm. Finally, by keeping constant the length of the ST device, he or she will receive a load on lower body of 51.3% body mass during flexion phase, corresponding to 33.3 kg. Therefore, to receive a maximum load of 35 kg on upper body, the subject will have to set the length of the ST device to 151.6 cm, with a minimum load of 31.7 kg.

Although a previous study demonstrated that men have more skeletal muscle mass than women especially in the upper body (19), the proposed equations of estimation of load distribution could be applied to both sexes of any human model because the variations from the anthropometric (body mass and limb length) parameters of the standard human model are only minimal. In fact, because human body is composed of tissues that get distorted when body changes position, determining the moment of inertia is a difficult task, and in most cases, the segments of the body are assumed to be rigid (21). Therefore, in the proposed models, no sex-related differences were taken into consideration because a man and a woman with the same body mass and height (i.e., same BMI) should have the same load distribution between upper and lower body.

The proposed models could provide different methods to objectively quantify the training load distribution, with the use of the straps' length resulting easier and faster with respect to the angle measurement. However, if practitioners will be able to evaluate the body inclination angle (by means of a goniometer), both equations can be used. The use of these equations could assist practitioners and instructors during the training session to personalize the workout to reach specific purposes. Furthermore, the manufacturing firms of these devices could endow the straps with length indicators, by making their length easier to regulate, particularly in according to the individuals' needs and aims during workouts.

Acknowledgments

The authors express their gratitude to Prof. Dr. Bruno Federico whose statistical expertise was invaluable during the analysis of the data, to Francesco Di Siena, Alice Iannaccone, Gabriel Risi, Arianna Tullio, and Giovanni Valente who collaborated in the data acquisition, and to the subjects involved in the study for their committed participation. G. F. Giancotti and A. Fusco equally share the main responsibility for conducting this research work.

References

1. Aguilera-Castells J, Buscà B, Fort-Vanmeerhaeghe A, Montalvo AM, Peña J. Muscle activation in suspension training: A systematic review. *Sports Biomech* 14: 1–21, 2018.

2. Allison K, Cervantes S. *Strength Training System and Method Having Elastic Resistance and Suspension Devices. U.S. Patent No. 9,345,922*. Washington, DC: U.S. Patent and trademark office, 2016.
3. American College of Sports Medicine. Position stand: Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 41: 687–708, 2009.
4. Behm DG, Anderson KG. The role of instability with resistance training. *J Strength Cond Res* 20: 716–722, 2006.
5. Behm DG, Muehlbauer T, Kibele A, Granacher U. Effects of strength training using unstable surfaces on strength, power and balance performance across the lifespan: A systematic review and meta-analysis. *Sports Med* 45: 1645–1669, 2015.
6. Bettendorf B. Customizing Intensity with the TRX. In: *TRX Suspension Training Bodyweight Exercises: Scientific Foundations and Practical Applications*. San Francisco, CA: Fitness Anywhere Inc, 2010. pp. 6–7.
7. Campa F, Silva AM, Toselli S. Changes in phase angle and handgrip strength induced by suspension training in older women. *Int J Sports Med* 39: 442–449, 2018.
8. Dannelly BD, Otey SC, Croy T, et al. The effectiveness of traditional and sling exercise strength training in women. *J Strength Cond Res* 25: 464–471, 2011.
9. Dudgeon WD, Herron JM, Aartun JA, et al. Physiologic and metabolic effects of a suspension training workout. *Int J Sports Sci* 5: 65–72, 2015.
10. Fenwick CM, Brown SH, McGill SM. Comparison of different rowing exercises: Trunk muscle activation and lumbar spine motion, load, and stiffness. *J Strength Cond Res* 23: 1408–1417, 2009.
11. Garnacho-Castaño MV, Domínguez R, González AM, et al. Exercise prescription using the Borg rating of perceived exertion to improve fitness. *Int J Sports Med* 39: 115–123, 2018.
12. Giancotti GF, Fusco A, Iannaccone A, Cortis C. Short-term effects of suspension training on strength and power performances. *J Funct Morphol Kinesiol* 3: 51, 2018.
13. Giancotti GF, Fusco A, Varalda C, Capranica L, Cortis C. Biomechanical analysis of suspension training push-up. *J Strength Cond Res* 32: 602–609, 2018.
14. Gulmez I. Effects of angle variations in suspension push-up exercise. *J Strength Cond Res* 31: 1017–1023, 2017.
15. Harris S, Ruffin E, Brewer W, Ortiz A. Muscle activation patterns during suspension training exercises. *Int J Sports Phys Ther* 12: 42–52, 2017.
16. Hass CJ, Feigenbaum MS, Franklin BA. Prescription of resistance training for healthy populations. *Sports Med* 31: 953–964, 2001.
17. Hetrick RA. *Exercise Device Grips and Accessories for Exercise Devices. U.S. Patent No. 7,090,622*. Washington, DC: U.S. Patent and Trademark Office, 2006.
18. Huang JS, Pietrosimone BG, Ingersoll CD, Weltman AL, Saliba SA. Sling exercise and traditional warm-up have similar effects on the velocity and accuracy of throwing. *J Strength Cond Res* 25: 1673–1679, 2011.
19. Janssen I, Heymsfield SB, Wang Z, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. *J Appl Physiol* 89: 81–88, 2000.
20. Kibele A, Behm DG. Seven weeks of instability and traditional resistance training effects on strength, balance and functional performance. *J Strength Cond Res* 23: 2443–2450, 2009.
21. Krishnan RH, Devanandh V, Brahma AK, Pugazhenthi S. Estimation of mass moment of inertia of human body, when bending forward, for the design of a self-transfer robotic facility. *J Eng Sci Technol* 11: 166–176, 2016.
22. Maté-Muñoz JL, Monroy AJ, Jodra-Jiménez P, Garnacho-Castaño MV. Effects of instability versus traditional resistance training on strength, power and velocity in untrained men. *J Sports Sci Med* 13: 460–468, 2014.
23. Melrose D, Dawes J. Resistance characteristics of the TRX™ suspension training system at different angles and distances from the hanging point. *J Athl Enhancement* 4: 1–5, 2015.
24. Mok NW, Yeung EW, Cho JC, et al. Core muscle activity during suspension exercises. *J Sci Med Sport* 18: 189–194, 2015.
25. Norman GR, Streiner DL. *Biostatistics: The Bare Essentials* (4th ed.). Shelton, CT: People's Medical Publishing House, 2014.
26. Prokopy MP, Ingersoll CD, Nordenschild E, et al. Closed-kinetic chain upper-body training improves throwing performance of NCAA Division I softball players. *J Strength Cond Res* 22: 1790–1798, 2008.
27. Ronai P, Scibek E. The suspension inverted row. *Strength Cond J* 36: 94–97, 2014.
28. Snarr RL, Esco MR. Comparison of electromyographic activity when performing an inverted row with and without a suspension device. *J Exerc Phys Online* 16: 51–58, 2013.
29. Snarr RL, Nickerson BS, Esco MR. Effects of hand-grip during the inverted row with and without a suspension device: An electromyographical investigation. *Eur J Sports Exerc Sci* 3: 1–5, 2014.