

## Determination of body weight before and after a headstand: the wrestling myth

Acuña-Espinoza, A.A. and Aragón-Vargas, L.F.

Human Movement Science Research Center, University of Costa Rica, Costa Rica.

Address for correspondence:

Luis F. Aragón-Vargas, Ph. D., FACSM  
Human Movement Science Research Center  
University of Costa Rica 11-501-2060  
Montes de Oca, San José, COSTA RICA.  
Ph. +506-2511-2790. Fax +506-2225-0749.  
E-mail: LUIS.ARAGON@ucr.ac.cr



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## ABSTRACT

Despite rules by NCAA to discourage extreme weight loss measures, the culture of wrestling still includes varied methods to make weight, including holding a headstand position for about 30s immediately before stepping on the scale. The procedure, according to the myth, will reduce reported mass anywhere between 250 and 500g. The aim of this study was to compare any possible differences between the headstand procedure (HS) and a normal (control, CON) weight measure, using a metrological approach defined by the European Association of National Metrology Institutes to evaluate the equipment being used. Seventeen adult men were weighed on a force plate before and after doing a headstand or standing normally for 30s; the order of treatments was assigned randomly. Post-test weight was significantly larger than pre-test ( $640.7 \pm 62.8$  N and  $640.3 \pm 62.7$  N, respectively,  $p < 0.05$ ) under both treatments, no treatment vs. time of test interaction was found. No significant difference was found between CON and HS weight ( $640.6 \pm 62.8$  N and  $640.9 \pm 62.9$  N, respectively,  $p > 0.05$ ). The metrological tests suggest statistical differences found are related to the platform's measuring errors in every pre-established time interval. The 45g difference found between pretest and post-test lies within the uncertainty range found for the equipment ( $\pm 0.11$  kg). In conclusion, a 30-second headstand has no significant effect on registered body weight. The small variations obtained were due to equipment-associated measuring errors. This experiment offers systematic empirical evidence to aid in the elimination of this unjustified practice among the wrestling community. **Key Words:** DYNAMIC STABILITY, GROUND REACTION FORCE, INDICATION ERROR, RESOLUTION, UNCERTAINTY

## INTRODUCTION

A myth among wrestlers and wrestling trainers stands that if a man remains in a headstand position for near 30 seconds, returning immediately afterwards to an upright position, his reported mass will decrease anywhere between 250 grams and 500 grams, improving his chances to achieve a lower weight class. This issue keeps coming up despite its apparent nonsense. Some wrestlers apply this technique immediately before weighing for competition as their last effort to make weight. Several explanations for this claimed decrement have been put forward but, to our knowledge, a formal scientific test of this issue has not been published. As weight regulations become more restrictive and NCAA encourages healthy nutrition and hydration practices, together with more comprehensive testing (2), wrestlers may resort to accessible methods to achieve a required weight: it has been observed during interscholastic wrestling season at the U.S. that some competitors jump four or more weight classes within a month (2).

The first explanations which would come to mind have to do with equipment errors or chance; while neither one is in fact a systematic error (sometimes weight would be higher, sometimes lower), it is desirable to know the magnitude of the equipment associated error. A brief explanation is warranted: one would expect that an object with a known mass, e.g., 40.0 kg, would weigh exactly 40.0 kg every single time it is placed on a properly calibrated weight scale, but it does not. Objects which have been certified according to strict criteria are classified in specific weight classes and may be called Calibration Weights (4). A Calibration Weight may be used to characterize the behavior of a measuring device. But our measurement problem involves human beings, which are a bit more complex than a static object.

Other somewhat reasonable explanations for the wrestler's myth phenomenon have been attributed to fluid movements within the body, and balance distortions. When measuring body weight, the human body is apparently in static equilibrium, but as in any live/dynamic body there exists a natural frequency (7) which could be understood as a slight "regular vibration" present in humans, possibly associated with one or more factors (e.g. heart rate, anatomical posture misshapes, muscular fatigue, mass/fluids redistribution). This natural frequency may be registered by a scale or a force platform. A dramatic variation of regular posture such as remaining in a headstand position could alter this regular vibration pattern, possibly altering the previous natural frequency. Once returning to an upright position, these vibratory alterations could modify the pattern by which the vertical ground reaction force is being interpreted by a low frequency weight measuring device. This device registers weight values in order to obtain an averaged measure, the final reading obtained by a judge. In short, the natural frequency of the human body might be disturbed enough to alter the weight readings.

In the end, *reported weight* could be different from the *true weight value* that should be actually reported by the equipment, not necessarily because of equipment error but because of changes in the person being measured. The aim of this study was to compare any possible differences between a normal (control) weight measure and that obtained after remaining in a headstand position for at least 30 seconds. We first evaluated the equipment used to measure body weight utilizing a strict metrological approach, thus supporting the quality of our reported results and enabling us to assess whether the differences –if any– were beyond equipment quantified error. To our knowledge, this is the first study that presents a systematic approach to this problem, using highly reliable equipment with its respective reported expanded uncertainty.

## METHODS

### Experimental approach to the problem

The main variable under study was *body weight* (B.W.). B.W. is the vertical pull exerted by the gravitational force on the subject *in situ*. Its unit, Newton (N) is defined as the subject's mass (kg) multiplied by the acceleration corresponding to gravity ( $m/s^2$ ).

There are several assessments related to the quality of a measure: precision, exactitude, indication error, expanded uncertainty and critical error. *Precision* (6) is the degree to which repeated measures on a same mass show the same result. *Accuracy* (6) estimates how close a weight measurement of a reference mass is to the true value of the mass.

*Indication error* involves both precision and exactitude. It is the difference between a weight's true value and that indicated by the equipment utilized to measure it at a specific time interval.

Its mathematical expression results:

$$E_j = I_L - I_0 - g \cdot \sum m_{ref}, \quad [1]$$

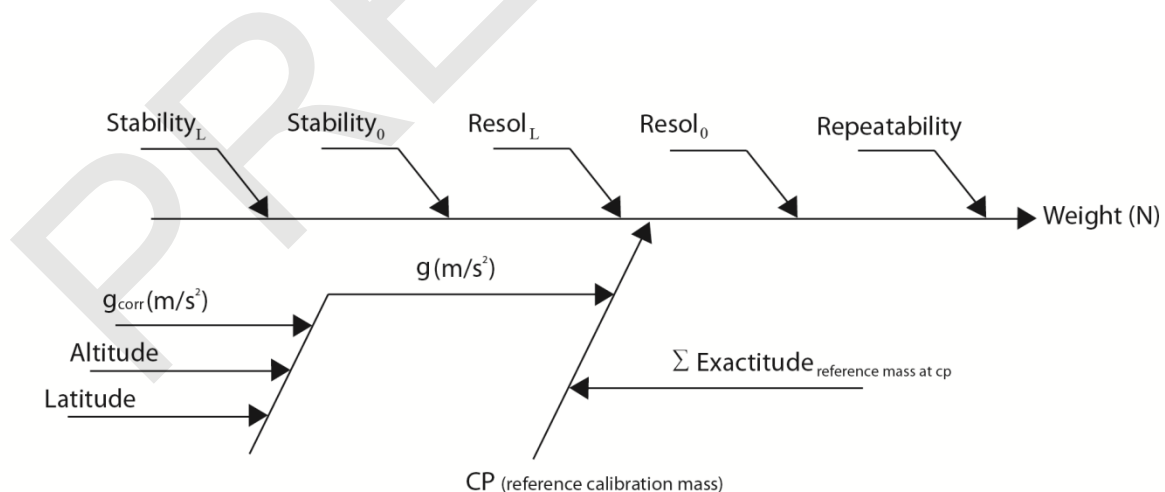
where  $I_L$  stands for an average weight indication in newton (N) at a determined load,  $I_0$  (N) stands for an average indication when the platform is completely unloaded and  $\sum m_{ref}$  is the sum of the reference weights in kilograms (kg) used at a determined load, which is being multiplied by the gravitational force *in situ*  $g_{corr} \approx 9.78 \text{ m/s}^2$ . *Expanded uncertainty* also involves exactitude and precision. It is an established range where the true value for a weight measurement can be effectively found. This range is defined for a specific time interval. Expressed as:

$$U = k \cdot u_c(y), \quad [2]$$

where coverage factor  $k = 2$  allows a more conservative approach by duplicating the combined uncertainty  $u_c(y)$  which is composed of the square sum of several uncertainties. These uncertainties are calculated according to EURAMET/cg-18/v.02 (1), and the Guide for the expression of the uncertainty (5), but in general terms, they are related to the following tests: loaded equipment resolution, unloaded equipment resolution, equipment repeatability, equipment stability when loaded, equipment stability when unloaded, the sum of the expanded uncertainties of the weights used at each *calibration point* (cp) and the standard uncertainty due to gravitational force *in situ* (Fig. 1). The *critical error* (is the combined result of the indication error and the expanded uncertainty, expressed as:

$$\text{Error}(t, cp) = E_j(t, cp) \pm U(t, cp), \quad [3]$$

where both  $E_j$  and  $U$  are time-interval and calibration-point dependent. In the present study, critical error resulted to be only time dependent due to the use of a same calibration point for every subject in the study ( $cp = 80 \text{ kg}$ ). Critical error allows us to report our results knowing they are within a trusted range, relative to the measuring equipment used.



**Figure 1. Cause-effect diagram associated to weight measure.**

## Subjects

Seventeen adult men ( $22.5 \pm 3.4$  years,  $66.0 \pm 6.7$  kg,  $173.7 \pm 4.7$  cm) volunteered to participate in this study. Statistical power calculations ( $\beta=0.001$ ) estimated that the  $n=17$  group, allows to determine a 250 g expected effect appropriately. All participants signed their informed consent. The institution's Science and Ethics Committee approved the research project. Regardless of habitual physical activity level, the compulsory requirement to participate in this study was their ability to remain in a headstand position for at least 30 seconds.

## Procedures

### Instrumentation

All vertical ground reaction force (GRF) determinations were performed through direct data acquisition using a Bertec<sup>TM</sup> force platform (Model: 6090-15) at a sampling rate of 1000 Hz for a 60 s period for each repetition. The platform's critical errors were determined for each of 16 test time intervals considered for the total time of each weight measurement repetition: 0-1 s, 1-2 s, 2-3 s, 3-4 s, 4-5 s, 5-10 s, 10-15 s, 15-20 s, 20-25 s, 25-30 s, 30-35 s, 35-40 s, 40-45 s, 45-50 s, 50-55 s and 55-60 s. Also at 5 calibration points (*cp*): 0 kg, 40 kg, 80 kg, 120 kg and 140 kg.

The nine reference masses: 6 of 20 kg each (expanded uncertainty,  $U=75$  mg), 1 of 10 kg ( $U=58$  mg) and 2 of 5 kg each ( $U=58$  mg), all of them M1 class according to OIML R 111-1 (4), in property of LABCAL<sup>1</sup> which were used to achieve the platform's calibration, were organized to guarantee that for each calibration point (*cp*) the same reference mass would be used, thereby determining the force platform associated *Errors*(*t*, *cp*). These *Errors* were calculated for 2

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<sup>1</sup> [www.inii.ucr.ac.cr/labcal/](http://www.inii.ucr.ac.cr/labcal/)

specific areas on the platform where the participants would place their feet. The expression of the measured weights resulted:

$$\text{Weight } (N) = \text{Reported weight } (N) + \text{Error} \quad [4]$$

applying [3] becomes,

$$\text{Weight } (N) = \text{Reported weight } (N) + E_j(t, cp) \pm U(t, cp) \quad [5]$$

As explained before, the  $U$  is a derivate result of the  $u_c(y)$  [2]. This last value was determined applying a series of tests that composed the device calibration procedure. The platform and its associated electronic devices were turned on 45 minutes before the calibration began: an awaiting time recommended by LABCAL for the stabilization of electronic signals. It was decided to evaluate the platform for a [40, 120] kg work range, so selecting 5 cps, including one below (0 kg) and one over (140 kg) the work range. For a matter of strictly technical advice, each of the tests performed will be addressed without going into details about their mathematical approaches (for further details, see EURAMET/cg-18/v.02 and the Guide for the expression of the uncertainty). The first test, called the *stability test* consisted of three weight measurement repetitions, in two conditions: (1) with the platform completely unloaded and (2) weighing a constant mass value of 40 kg ( $\approx 0.3 \cdot cp_{\text{Max}}$ ) (3), every measurement repetition for a 60 s period at 1000 Hz. These allowed determining two stability uncertainties: for unloaded ( $\mu_{\text{stability}0}$ ) and loaded ( $\mu_{\text{stability}L}$ ) equipment (Figure 1), intimately related to the equipments exactitude. The next test called the *repeatability test* evaluated platform's precision and consisted in the repeated loading of the equipment for two conditions: 50% and 100% of the  $cp_{\text{Max}}$  (140 kg). An 80 kg load was symmetrically distributed over the two platform calibrated areas, and then a 60 s



measurement was made using the same 1000 Hz measurement frequency. The platform was unloaded and then loaded over and over for a total of 10 repetitions. The same procedure was applied utilizing a 140 kg load. Uncertainty due to repeatability ( $\mu_{\text{repeatability}}$ ) was calculated for each of the predefined time intervals and for both loads. The higher  $\mu_{\text{repeatability}}$  from the two loads was assigned to each of them, thus utilizing the critical  $\mu_{\text{repeatability}}$  value at each time interval.

Indication errors were calculated for each cp utilizing [1]. This test is known as the *indication test* and it is associated with both precision and exactitude. When the indication errors were calculated for each cp, a predefined set of the reference masses was utilized. Therefore, as each set would vary, also the uncertainty associated with the reference masses on each cp varied. Uncertainty associated with the reference masses utilized can be divided into three independent uncertainties, all of them directly related to these reference masses properties: reference mass uncertainty ( $\mu_{\text{reference-mass}}$ ), reference mass uncertainty due to drift ( $\mu_{\text{drift}}$ ) and reference mass uncertainty due to gravitational force *in situ*  $\mu_{\text{gcorr}}$  (9). The  $\mu_{\text{reference-mass}}$  corresponds to the arithmetic sum of the uncertainties reported at the calibration certificates of each reference mass utilized to evaluate a single cp. The  $\mu_{\text{drift}}$  is calculated for each group of reference weights utilized and is associated with its wear and tear over time. The  $\mu_{\text{gcorr}}$  depends on altitude and latitude where the reference masses were utilized and also on a correction factor according to OIML R 111-1. The last uncertainty utilized to determine the  $u_c(y)$  (a.i. [2]) was due to the equipment's *resolution*  $\mu_{\text{resol}}$ . It resulted to be the same either when the platform was loaded ( $\mu_{\text{resolL}}$ ) or unloaded ( $\mu_{\text{resol0}}$ ). The geometric sum of these uncertainties composes the  $u_c(y)$ :

$$u_c(y) = \left( (\mu_{\text{stabilityL}})^2 + (\mu_{\text{stability0}})^2 + (\mu_{\text{repeatability}})^2 + (\mu_{\text{reference-mass}})^2 + (\mu_{\text{drift}})^2 + (\mu_{\text{gcorr}})^2 + (\mu_{\text{resolL}})^2 + (\mu_{\text{resol0}})^2 \right)^{\frac{1}{2}} \quad [6]$$

During these procedures, two additional uncertainties are also commonly determined. One is the uncertainty on the measurement due to the variation on the specific location of the measured mass at the area on the platform where it can be effectively measured, known as uncertainty due to eccentricity ( $\mu_{\text{eccentricity}}$ ). The other one is the uncertainty due to differences that may be found on several measurements on a same mass, when this mass is involved in a procedure where different masses are being randomly measured. E.g. when in a 3 measurements procedure, a different weight value is reported by the measuring device on a 40 kg mass, if the first measure evaluated a 40 kg mass, the second measure a 60 kg mass and the third one the same 40 kg mass. This last uncertainty is called uncertainty due to hysteresis ( $\mu_{\text{hysteresis}}$ ). The  $\mu_{\text{eccentricity}}$  was discarded due to the fact that two specific areas on the platform were chosen and calibrated, and the masses were symmetrically distributed on them during this platform's calibration procedure. Consequently, the experiment procedure was designed so the participants must place their feet exclusively on those pre-established areas. The  $\mu_{\text{hysteresis}}$  was evaluated by applying a test that consisted in progressively loading the platform while a single measurement was applied at each cp (from 0 kg to 140 kg) and then progressively unloading it (from 140 kg to 0 kg). The two measurements for each cp (one during loading and the other during unloading) were compared and  $\mu_{\text{hysteresis}}$  discarded applying inferential statistics.

### **Testing protocol**

Upon arrival for testing, participants read, discussed and signed the experimental protocol consent form. Their age was queried and their height was measured. Participants were randomly assigned to one of two groups, which performed the tests in different conditions: one group was

measured before and immediately after standing normally for 30 seconds; then they were measured before and immediately after 30 seconds in a headstand position. Individuals in the other group did the headstand measurement first. Each participant was weighed a total of 4 times: before and after the headstand treatment, and before and after the control. Each time the participants were measured, they stepped on the force platform and stood still in the fundamental anatomical position, with their feet placed over the platform calibrated areas, to register B.W. for a total of 60 s. Raw data were exported to a Microsoft EXCEL® spreadsheet to determine average values for each of the 16 predefined time intervals mentioned above. This information was then analyzed through inferential statistics.

### **Statistical Analyses**

A repeated measures 2X16, 2-way ANOVA design (loading by time interval) was utilized to evaluate the presence of platform's  $\mu_{\text{hysteresis}}$ . Descriptive statistics were calculated for participant's age and height. B.W. was analyzed using a repeated measures 2X2X16, 3-way ANOVA design (condition by time interval by treatment). Statistical significance was chosen at  $p < 0.05$ .

## **RESULTS**

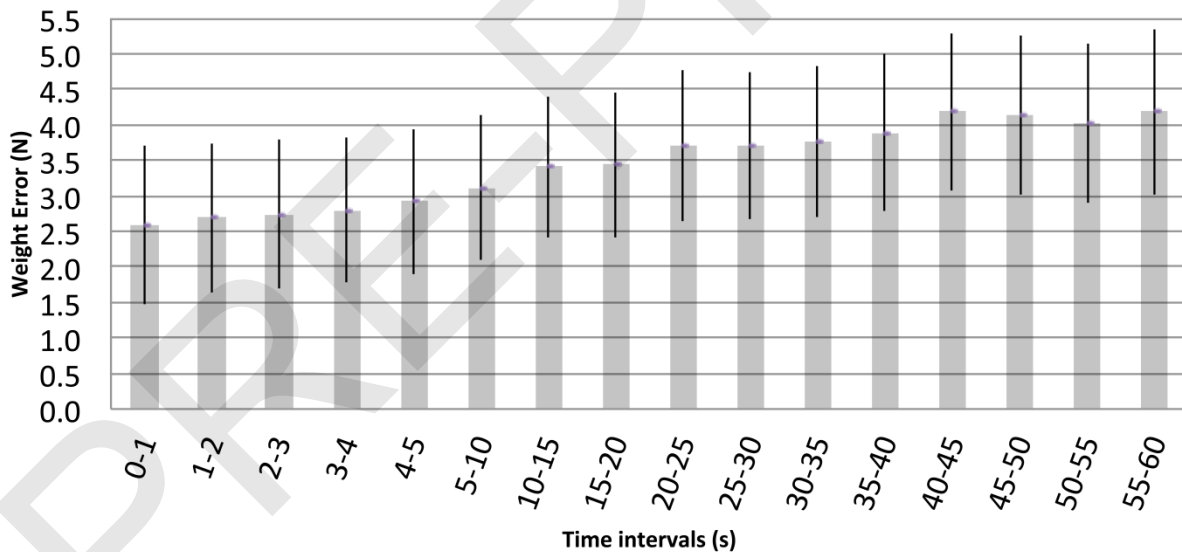
### **Measuring instrument performance**

Regarding hysteresis, no significant differences ( $F: 2.96, p < 0.05$ ) were found for any of the calibration points (0, 40, 80, 120, and 140 kg). These cps were used during both, instrument calibration and participant testing. All the participants were found to be between the 40 kg cp ( $\approx 391$  N) and the 80 kg cp ( $\approx 782$  N), specifically between 581 and 713 N. Between these cps, the

higher indication errors and  $U$  found for all the test time intervals during the calibration procedure belonged to the 80 kg cp, thus allowing the definition of all the *critical errors* for each time interval on that same cp, becoming exclusively time dependent. Therefore, [5] results:

$$\text{Weight} = \text{Reported weight} + E_j(t) \pm U(t) \quad [7]$$

The errors utilized to report the weight results for the different time intervals (a.i [3]) are summarized in Fig. 2.  $E_j(t)$  was found to be unilateral, with a platform value higher than the reference mass value being evaluated; it increased over time. Meanwhile  $U(t)$  exhibited a bilateral behavior, thus defining a symmetric range (Fig. 2). As an example, the error associated to the [0, 1] s interval was found to be  $2.6 \pm 1.1$  N (a.i. [3]). An uncertainty of  $\pm 1.1$  N is equivalent to a  $\pm 0,12$  kg mass value.



**Figure 2. Error (N) associated to 80 kg cp by time intervals: bar heights represent indication error ( $E_j$ ) and the vertical lines the expanded uncertainties ( $\mu_{exp}$ ).**

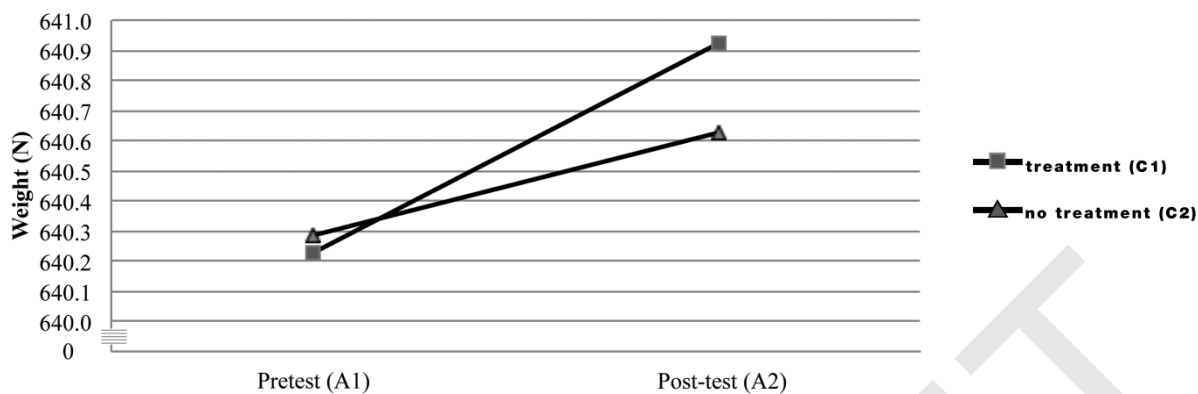
### Subject response to the treatment

The results of the 3-way ANOVA are summarized in Table 1. There was no significant interaction between condition (A) and treatment (C), and no difference between treatment (C1) and no treatment (C2). No significant difference was found between normal weight and weight after a 30-second headstand ( $640.6 \pm 62.8$  and  $640.9 \pm 62.8$ N, mean  $\pm$  s.d. respectively,  $p > 0.05$ ) (Fig. 3). However, post-test weight (A2) was significantly larger than pre-test (A1) ( $640.8 \pm 62.8$  and  $640.3 \pm 62.7$ N, respectively;  $F: 24.15^*$ ,  $p \leq 0.05$ ).

Source	Sum of squares	DF	Mean squares	F ratio
Pretest-Posttest (A)	73.58	1	73.58	<b>24.15*</b>
Time intervals (B)	2.74	15	0.18	<b>2.44*</b>
With/without headstand (C)	3.94	1	3.94	0.81
A*S	48.75	16	3.05	-
B*S	18.03	240	0.08	-
C*S	77.64	16	4.85	-
A*B	4.04	15	0.27	<b>6.55*</b>
A*C	8.90	1	8.90	1.25
B*C	0.31	15	0.02	0.43
A*B*S	9.88	240	0.04	-
A*C*S	113.78	16	7.11	-
B*C*S	11.59	240	0.05	-
A*B*C	0.93	15	0.06	1.34
A*B*C*S	11.04	240	0.05	-
S	4278067.40	16	267379.21	-
T	4278452.55	1087	3936.02	-

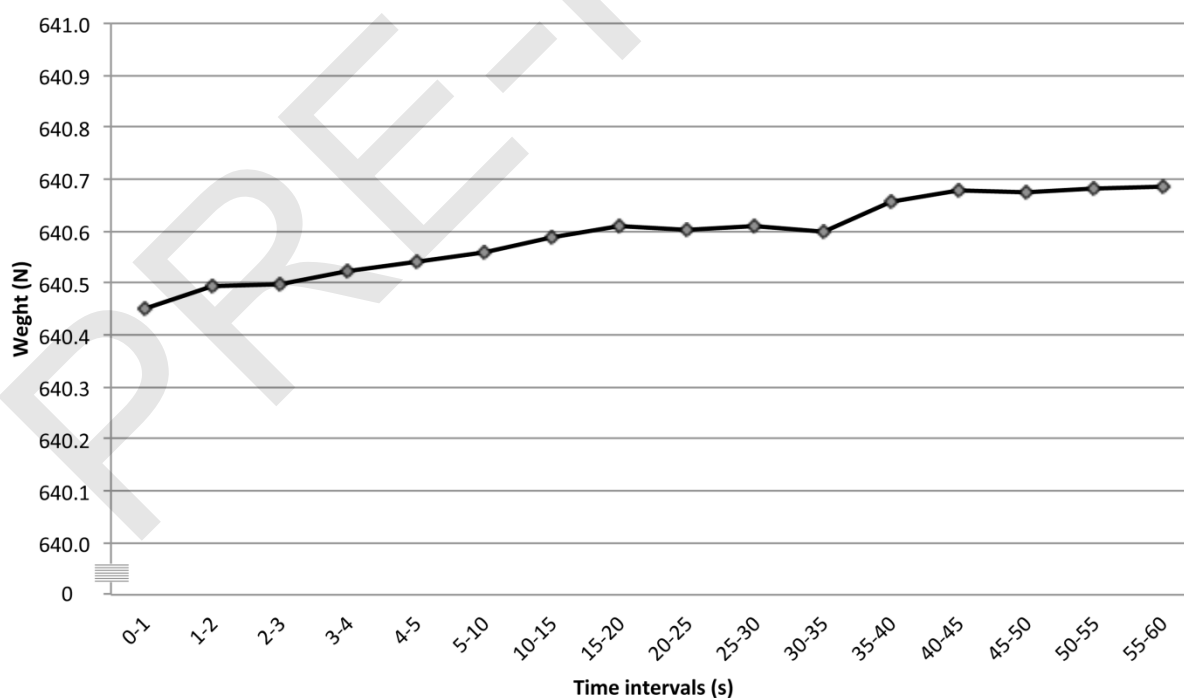
**There was a significant difference(\*) between Pretest-Posttest as well as among time intervals. Only the A\*B interaction resulted significant ( $p \leq 0.05$ )**

**Table 1. 3-way ANOVA: condition by time interval by treatment.**



**Figure 3. Interaction: order vs. treatment.**

Results show that the Post-test average weight was greater than the Pretest by 0.44 N (approximately 0.045 kg). A significant difference was found among the test time intervals into which each test was divided ( $F: 2.43^*$ ,  $p \leq 0.05$ ; Fig. 4). Additionally, the condition (A) vs. test time intervals (B) interaction was also significant ( $F: 6.55^*$ ,  $p \leq 0.05$ ).



**Figure 4. Averaged weight (N) measured at pre-established time intervals.**

Overall, experimental results regarding the participant's evaluation are consistent with the results exhibited during the platform's calibration: participant's weight measures increased over time at both pretest and post-test and during both treatment conditions (Fig. 4), as  $E_j(t)$  did during calibration (Fig. 2).

## DISCUSSION

None of the results comparing the application to the non-application of treatment were found to be significant. In general, experimental results suggest that statistical differences found are directly related to the platforms' accuracy and are not due to the treatment. **The main result from this study was that there is no effect of headstand (C) on weight variability.** However, the analysis also suggests not only that the previously quantified platform's  $E_j(t)$  increment over time exists ( $F: 9.3, p < 0.05$ ) but also that the unloading time of the platform may lie beyond 30 seconds. This last issue due to the statistical significance found between pre-test (A1) and post-test (A2) measures: the findings suggest that, after completely removing a load from the platform, it does not begin to register a complete unload after 30 s or more. The results regarding headstand are not surprising: B.W. should not be altered by a single postural change, rather than due to other activities that imply significant mass changes in a relative short period (a couple hours) as e.g. exercise (that may lead to important fluid losses through sweating) or urinating. In general, these experimental results suggest that statistical differences found are directly related to the platforms' measuring errors and are not a consequence of the treatment.

The experimental design based upon the random assignment of the treatment order and also utilizing the same participants for both experiment and control conditions, provides a pertinent approach to the research problem, aiding at the variance control. In human locomotion, the

highest voluntary frequency is less than 10 Hz (8) consequently a low-frequency of 20 Hz according to the Sample Theorem (10) would be more than enough to minimize movement artifacts. A useful biomechanical sample frequency of 1000 Hz was utilized, thus providing a very accurate, time dependent weight measurement that would minimize the risk of missing peak values (8).

This research was conducted in such a way to allow high reproducibility, while being conservative on its approach by ensuring high compliance with metrological guidelines: it was possible to associate an error (a.i. [3]) to each weight measurement in every pre-established time interval. This allows for a stronger analysis that gives exactitude and accuracy a critical role, rather than being limited by just a statistical analysis which, while providing a strong mathematical approach, poses the risk of omitting practical findings.

Considering both the results from the platform calibration and the human tests, the pretest weight with its reported associated error at the [0,1] s interval was found to be  $640.3-2.6\pm 1.1$  N (a.i. [7]), that is  $637.7\pm 1.1$  N. Post-test weight at the same time interval was found to be higher:  $640.8-2.6\pm 1.1$  N, or  $638.2\pm 1.1$  N (Fig. 3.). The numerical difference found between the pretest and post-test results ( $\approx 45$  g) despite statistically significant, was negligible in light of the 1.1 N (0.11 kg) uncertainty: the difference lies within the uncertainty range. If we assume a dramatic scenario, in which the measurements are compared at the lower and higher points of the uncertainty range at the [0,1] s time interval, subtracting  $637.7-1.1=636.6$  N from  $638.2$  N+1.1 N=  $639.3$  N will result in a 2.7 N (0.27 kg) difference.

The unidirectional behavior of the indication error (Fig 2) and the absence of significant hysteresis ( $p<0.05$ ), focuses the attention on the reported, time dependent, expanded



uncertainties. Specifically, at the cp selected (80 kg), the maximum possible difference would lie between the 55-60 s interval, being of approx 2.33 N (237 g, Fig. 2) when considering the expanded uncertainty upper and lower limits (subtracting the lower limit to the upper limit). Within the first 5 seconds, it would be reduced to a maximum of approx 2.23 N (228 g). Taking into account expanded uncertainties at each time interval (at the 80 kg cp), when calculating the highest possible differences at the same time intervals, for pretest and post-test weight results, these differences vary between 2.43 N (approx. 249 g @ (1-2) s) and 3.04 N (approx. 311 g @ (55-60) s). The average value for the maximum possible differences at each time interval is of 2.65 N (271 g), a value over the minimum target difference of 250 g. In other words, when considering the most critical scenario regarding the quantified measurement's associated error, it is not possible to affirm the non-existence of mass differences below 271 g within one minute. It can be affirmed that, if existent, average differences between the weight at pretest and post-test are of  $\leq 271$  g and they **cannot be attributed to the effect of remaining in a headstand position** for approximately 30s. Numerical differences found among pretest and post-test results are much more lower than the  $U$  calculated for them: in a practical sense, there is no difference between pretest and post-test results, and in order to find them if existent, an even more accurate and exact measuring equipment should be use.

Finally, we dare to speculate that since we were able to quantify and to express a platform 'drift' and its significance ( $p < 0.05$ ), a difference in measured weight caused by the treatment (headstand), if present, should have been evident. The conducted research found no appreciable differences on a man's weight after remaining in a headstand position for approximately 30 s. The myth that has been spread among the wrestling discipline community is discarded by the

present study, finding no significant differences except for the 270 g between pretest and post-test measurements; this difference was independent from remaining in a headstand position.

## **PRACTICAL APPLICATIONS**

This study shows, through an experimental approach supported by a metrological approach, the falsehood of the myth among wrestlers and wrestling trainers that reported mass will decrease if a man remains in a headstand position for about 30 seconds and returns immediately afterwards to an upright position, hence improving his chances to achieve a lower weight class. This experiment offers systematic empirical evidence to aid in the elimination of this unjustified practice. We dare to speculate that since we were able to quantify and to express a platform 'drift' and its significance ( $p < 0.05$ ), a difference in measured weight caused by the treatment (headstand), if present, should have been evident. No appreciable differences on a man's weight after remaining in a headstand position for approximately 30 s were found. The myth is discarded by the present study, finding no significant differences except for the 270 g between pretest and post-test measurements; this difference was independent from remaining in a headstand position. Therefore, the athlete's effort to decrease his reported weight during the official weighing will not improve by remaining in a headstand position for about 30 seconds.

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