

VALIDATION OF A COMMERCIALY AVAILABLE STRAIN GAUGE AGAINST A SERIES OF KNOWN LOADS USING A SHORT TIME APPROACH

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The purpose of this study was to identify the content validity and accuracy of a commercially available strain gauge (GSTRENGTH (Exsurgo Technologies, Virginia, USA), aimed at use within athletic populations. Six standardised IWF (International Weightlifting Federation) calibrated weights (5-, 25-, 50-, 100-, 200-, 250-kg) were hung from the strain gauge and raw data was collected over a five-second period and exported to a computer. A perfect relationship between the known loads and the strain gauge ($r = 1.00$, $p < 0.001$) was identified, although the strain gauge was found to have a small overestimation error with no fixed or proportional bias. During data collection there were non-significant, trivial-small differences between the first and last second, demonstrating minimal drift. The commercially available strain gauge was found to be valid when compared to the known loads. Further investigation of the strain gauge is required to assess the concurrent validity when compared to gold standard methods of assessment, such as force plates, in a range of test designs.

KEYWORDS: content validity, performance assessment, strain gauge

INTRODUCTION: The assessment of force production in both isometric and dynamic conditions has been increasing in popularity within sporting environments, with an increase in the availability and affordability of testing devices (including force plates, hand-held dynamometers, and strain gauges). In the context of athlete force assessment, strain gauges typically measure force via an external tensile load, i.e., forces pulling against the device. The assessment of a “pulling” force can be achieved in concentric, isometric, or eccentric conditions, if a suitable set up can be established with a strain gauge device. Strain gauges are typically small devices with high levels of portability, therefore, enabling a wide range of methodological designs.

To date, the assessment of isometric and eccentric force production has been popular in sporting contexts, with significant relationships with athletic performance observed with the isometric mid-thigh pull (IMTP) and isometric squat (ISQ) (Kawamori et al., 2006; Stone et al., 2003; Thomas, Comfort, Chiang, & Jones, 2015; Thomas, Jones, Rothwell, Chiang, & Comfort, 2015; Wang et al., 2016), while an eccentric assessment of the hamstrings has also been identified as having some potential benefit in hamstring strain injury risk assessment (Bourne, Opar, Williams, & Shield, 2015; Green, Bourne, van Dyk, & Pizzari, 2020; Opar et al., 2015; Roe et al., 2020; Timmins et al., 2016), in addition to relationships to sprinting performance (Markovic et al., 2018). Therefore, the identification of accurate and meaningful methods of force-based assessment using strain gauges can be considered essential to be able to infer training status and the training needs of athletes. The GSTRENGTH strain gauge (Exsurgo Technologies, Virginia, USA), which has a maximal tolerable load of 700 kg, is a commercially available strain gauge aimed at practitioners working with athletic populations, with a range of multi- and single-joint tests pre-programmed into the accompanying application, including the IMTP and isometric belt squat (IBSQ). It could also be suggested more portable testing devices such as the strain gauge could be highly beneficial in practice, where the set-up of more structured testing devices (i.e., force plates) can become impractical, such as when working with elderly or disabled populations. A further consideration that should be made is if the components and the construction of the strain gauge is suboptimal then overtime the measures

of force could increase via drift due to increasing time rather than load. However, to date no research has looked to observe the content validity of this commercially available strain gauge. Therefore, the measurements of forces attained from these devices needs to be assessed for accuracy and content validity, prior to being used to infer and inform training practices. The aim of this study was to assess the content validity of a commercially available strain gauge, via the hanging of known IWF (International Weightlifting Federation) calibrated weights. It was hypothesised that the commercially available strain gauge would possess high levels of content validity with minimal bias.

METHODS: Six known loads ranging between 5-250 kg (5-, 25-, 50-, 100-, 200-, 250-kg) using 5-kg and 25-kg IWF calibrated weights training plates (Werksan, Ankara, Turkey, Eleiko, Halmstad, Sweden), were hung off a GSTRENGTH strain gauge (Version 2, Exsurgo Technologies, Virginia, USA) using carabiners and a high strength nylon climbing sling (Figure 1).



Figure 1. 250-kg hanging from GSTRENGTH strain gauge with output USB connector.

Prior to data collection the GSTRENGTH strain gauge was initially zeroed following which all loads were hung for a 4-minute period to stabilise, to avoid any fluctuations in the force data via any swinging motion. The strain gauge was connected via USB to a MacBook computer (Apple, California, USA) and data were collected at 80 Hz over a five-second period using a terminal emulator (Serial, version 1.4.11, Decisive Tactics, inc., Virginia, USA), with one trial per load. Data were saved as text files and then opened and analysed in a custom designed Excel Spreadsheet (Microsoft Corporation, Washington, USA). The raw data output from the GSTRENGTH strain gauge is collected as kilograms (kg).

The mean, standard deviation (SD) and typical error (TE) of the loads across the 5-second period was determined. Absolute error, absolute percentage error and root mean squared error (RMSE) and standard error of the estimate (SEE) were calculated. To observe the relationship between the known loads and the GSTRENGTH strain gauge, an ordinary least squares (OLS) regression analysis was performed with the prediction equation and coefficient of determination (R^2) also identified. Using the OLS regression, the 95% confidence intervals (CIs) for the slope and intercept were used to determine if any differences between the known loads and the GSTRENGTH strain gauge were subjected to fixed or proportional bias. Fixed bias was considered to be present if the CI for the intercept does not include zero, whereas proportional bias was considered to be present if the CI for the slope does not include one. Finally, to determine if there was any drift in the data across the collection period, the first second (0-1 second) and last second (4-5 seconds) were compared using a paired samples t-test and Cohen's d effect size. All statistical analyses were performed using a custom Excel spreadsheet and SPSS (SPSS version 25, IBM, Armonk, NY, USA). A significance value was set at $P < 0.05$.

RESULTS: The mean, standard deviation (SD) and typical error (TE) of each of the know loads across the 5-second period is presented in table 1. Across all known loads, the RMSE and SEE was identified as 4.83 kg and 0.216. Despite a perfect relationship between the known

loads and GSTRENGTH strain gauge (Figure 2) ($R^2 = 1.00$), there was an incremental rise in the absolute error, absolute percentage error (Table 1) with increasing load.

Known Load (Kg)	5	25	50	100	150	200	250
Mean (kg)	5.04	25.69	51.47	102.93	154.80	207.19	258.78
SD (kg)	0.02	0.02	0.05	0.02	0.02	0.02	0.02
Typical error (kg)	0.01	0.01	0.03	0.02	0.02	0.01	0.01
Absolute Error (kg)	0.04	0.69	1.47	2.93	4.80	7.19	8.78
Absolute percentage Error (%)	0.78	2.76	2.95	2.93	3.20	3.60	3.51

The slope and intercept and corresponding 95% CIs identified there was no fixed or proportional bias between the known loads and the GSTRENGTH strain gauge (Table 2).

		95% LCI	95% UCI	Conclusion
Slope	1.04	0.60	1.47	No Proportional bias
Intercept	-0.32	-0.76	0.11	No Fixed bias

LCI = lower confidence interval, UCI = upper confidence interval

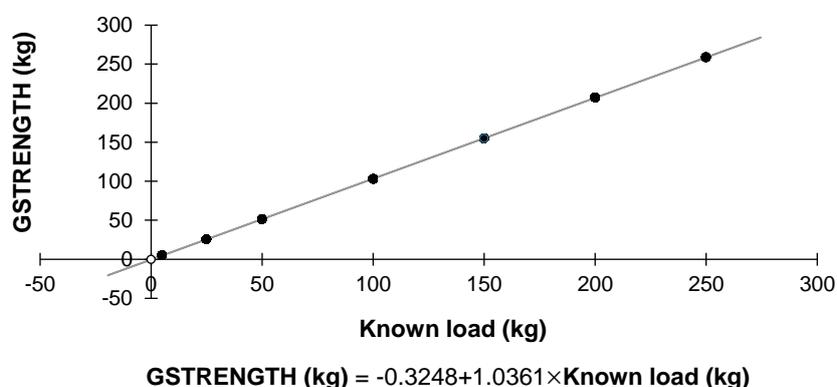


Figure 2. Ordinary least squares regression and prediction equation between known loads and the GSTRENGTH strain gauge.

Non-significant, trivial-small differences ($p > 0.103$, $d < 0.195$) were identified between the first and last seconds of data collection demonstrating there was no drift in the accuracy of the measurement during data collection.

DISCUSSION: The primary aim of the present study was to assess the content validity of a commercially available strain gauge, by the hanging of known loads. The GSTRENGTH strain gauge was found to be valid when compared to the known loads with a perfect relationship, however, there was an incremental overestimation error with an RMSE of 4.83 kg. This coincides with no fixed or proportional bias between the known loads and GSTRENGTH strain gauge. Across the six loads assessed the absolute error between the known load and that load attained using the GSTRENGTH strain gauge increased from 0.04 kg (0.78%) with 5 kgs up to 3.78 kg (3.51%) with 250 kg. As the overestimation could exponentially increase with the force output, i.e., larger errors could be expected with multi-joint compared to single-joint tasks, or even between tasks considered similar but different technical output (IMTP, ISQ and IBSQ). But as there is no fixed or proportional bias, comparing between varying tasks should be avoided. However, this requires further investigation and establishing the concurrent validity with gold standard methods of assessment (i.e., force plates) across performance tests such as the IMTP, ISQ and IBSQ, where these multi-joint assessments can reach into >5000 N (>500 kg) range in elite athletes. The secondary aim of the present study was to identify if there was any drift in data collection. Non-significant, trivial-small differences were observed between the first and last second of data collection, demonstrating there was no identifiable

drift during data collection. This could be critical for strength-endurance based assessments such as longer isometric assessments, where decreases in the force output could be expected due to fatigue and not down to technical error.

It is worth noting that, that the raw data that is acquired via the terminal emulator is attained in kg unit, which is unconventional when compared to gold-standard methods of assessment such as force plates, where data is collected in Newtons. Therefore, if future research was to compare the outputs between the GSTRENGTH strain gauge and force plates, values would have to be converted using the gravitational acceleration constant (9.81 m/s^2).

CONCLUSION: The commercially available strain gauge was found to possess content validity, when compared to the known loads, with a perfect relationship and zero drift despite an overestimation, which is not fixed or proportional. The system was found to be practical and functional when collecting data, potentially enabling the assessment of physical performance assessment within practice across a wide range of test designs. However, further investigation of the strain gauge is required to assess the concurrent validity when compared to gold standard methods of assessment, such as force plates in a range of test designs.

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