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Validation of the G-Force Platform for Isometric Tests in Physically Active Young Adults: A Pilot Study

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Academic Editors: Marios Hadjicharalambous and Nikolaos Zaras

Received: 6 November 2025
Revised: 21 November 2025
Accepted: 21 November 2025
Published: 22 November 2025

Citation: Garrido-Osorio, V.; Fuentes-Barría, H.; Aguilera-Eguía, R.; Roco-Videla, Á.; Quidel, M.; Romero-Vera, L.; Leschot-Gatica, J.; Sanhueza-González, S.; Ñancupil-Andrade, A.; Pérez-Castilla, A.; et al. Validation of the G-Force Platform for Isometric Tests in Physically Active Young Adults: A Pilot Study. *Appl. Sci.* **2025**, *15*, 12409. <https://doi.org/10.3390/app152312409>

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Abstract

Objectives: To evaluate the validity, accuracy, and reliability of the G-Force force platform during isometric tests, through comparison with a gold-standard force platform in physically active young adults. **Methods:** Nine physically active participants (23.67 ± 4.97 years; body mass index: 25.79 ± 3.02 kg/m²) performed isometric posterior lower limb muscle tests per leg, following a standardized warm-up and familiarization protocol. The G-Force platform and compared against a gold-standard device, the Valkyria Trainer Balance (VTB) force platform. The measured variables included Peak Force and peak rate of force development (RFD) at 50, 100 and 150 ms (RFD50, RFD100 and RFD150). Intra- and inter-platform reliability were assessed using intraclass correlation coefficients (ICC), standard error of measurement (SEM), coefficient of variation (CV%), Bland–Altman analysis and Pearson’s correlation coefficients between both platforms. **Results:** Peak Force showed excellent intra-platform repeatability (ICC = 0.86–0.91) and moderate-to-good inter-platform reliability (ICC = 0.75–0.77), with the G-Force platform generally reporting slightly lower absolute values than VTB. RFD measures demonstrated moderate reproducibility (ICC = 0.75–0.87) and higher variability (CV = 47–57%). Bland–Altman analyses revealed minimal bias for Peak Force, while regression analyses indicated strong, significant associations between G-Force and VTB measurements ($R^2 = 0.55–0.77$; $\beta = 0.74–0.88$; $p < 0.05$). **Conclusions:** The G-Force force platform is a valid, reliable, and low-cost tool for assessing isometric strength in physically active young adults.

Keywords: validation study; equipment and supplies; muscle strength; isometric contraction; adults

1. Introduction

Muscular strength is the ability of the neuromuscular system to generate tension against resistance and represents a key component for both physical performance and the prevention of musculoskeletal injuries [1,2]. Consequently, accurate assessment of the strength of different muscle groups allows for the characterization of an individual's functional status and the optimization of training programs, injury prevention strategies, and clinical progress monitoring [1,2].

In this context, sports sciences have been characterized by the continuous development of new strength training methods, which are frequently accompanied by technological advances aimed at evaluating and controlling the athletic training process [3–6]. However, conventional force platforms, considered the gold standard for strength measurement, present limitations in terms of cost, size, and technical complexity. These factors restrict their use to specialized laboratories and hinder their implementation in routine sports or clinical settings [4–6].

To address these limitations, portable low-cost force platforms have been developed, enabling the measurement of forces in multiple directions and the calculation of muscle contraction-related parameters such as maximum force, rate of force development (RFD), impulse, and jerk, among other metrics [7–10]. Currently, various types of force platforms are available on the market, notably uniaxial and biaxial designs. Specifically, uniaxial platforms are designed to measure forces applied in a single direction—typically the vertical plane—using a single load cell or a set of integrated cells that concentrate the measurement along a principal axis, thus providing precise data on the magnitude of the applied force in that plane [11]. In contrast, biaxial platforms allow simultaneous measurement of forces in two directions, typically vertical and horizontal (anteroposterior or mediolateral), offering a more comprehensive understanding of the movement dynamics between the support surface and the evaluated subject [12].

Moreover, both systems are particularly useful for assessing complex movements involving lateral displacements, pushes, or changes in direction, as they enable the calculation not only of vertical force but also of horizontal force vectors. Additionally, they provide metrics such as center of pressure, impulse, and balance, through load cells that convert the applied force into proportional electrical signals, offering real-time quantitative recordings via integration with specialized software [13–15].

Nevertheless, the accuracy and reliability of these platforms depend on each system's individual design, the calibration of its load cells, and the proper alignment of the subject during measurement [16]. Given the increasing use of low-cost force platforms in research and applied settings, it is essential to perform specific validation studies for each device and muscular test to ensure that the collected data are reproducible and truly representative of muscular performance. Accordingly, the present study aimed to evaluate the validity, accuracy, and reliability of the G-Force force platform for assessing maximal isometric hip strength in physically active young adults, using a gold standard as the reference.

2. Materials and Methods

2.1. Design

Observational, descriptive, cross-sectional exploratory pilot study conducted between October and November 2025 at the facilities of Universidad de las Américas in Concep-

ción, Chile. The study was designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [17]. The protocol was reviewed and approved by the Ethics Committee of University Central of Chile (Protocol code: 106/2025; Approval date: 30 October 2025). All participants provided written informed consent prior to inclusion, in compliance with the principles of the Declaration of Helsinki [18].

2.2. Context

In sports and clinical settings, the assessment of muscular strength is often limited by the high cost and technical complexity of available equipment [19]. In this context, the G-Force force platform emerges as a low-cost alternative based on a system of load cells and electronic sensors, which has demonstrated adequate reliability and repeatability in measuring isometric contractions [20]. Therefore, this study aimed to determine the accuracy and validity of the G-Force platform compared to a gold standard platform from the brand Ivolution (Rafaela, Argentina, Valkyria Trainer Balance model) in physically active young adults.

2.3. Participants

The study sample consisted of 9 adults aged 23.67 ± 4.97 years who attended the facilities of Universidad de las Américas in Concepción, Chile. Participants were recruited through non-probabilistic convenience sampling, including social media announcements and direct email contact with the researchers. Written informed consent was obtained from all participants prior to inclusion, in accordance with the ethical principles of the Declaration of Helsinki [18]. No priori power analysis was performed. This study was exploratory/pilot in nature, with a sample size limited by participant availability and resource constraints.

Physically active participants were defined according to the World Health Organization (WHO) guidelines: adults engaging in at least 150 min of moderate-intensity aerobic activity, or 75 min of vigorous-intensity activity per week, and performing muscle-strengthening activities involving major muscle groups at least two days per week [20]. Participants self-reported their weekly physical activity levels using a structured questionnaire and were included only if they met these criteria.

2.4. Eligibility Criteria

The inclusion criteria were adults aged 18 to 44 years who were physically active and capable of performing maximal voluntary contractions safely, abstaining from moderate or vigorous physical activity during the 48 h prior to each testing session to avoid interference from acute exercise responses, and able to read, understand, and sign the informed consent before participation. Exclusion criteria included a diagnosis of disabling musculoskeletal disorders or non-communicable chronic diseases (e.g., hypertension, diabetes, or other cardiovascular/metabolic conditions) that contraindicated maximal effort, use of medications that could affect muscular, neuromuscular, or cardiovascular function and potentially alter force generation or responses to maximal voluntary contractions, and inability to correctly perform the physical test according to the protocol instructions.

2.5. Instruments

2.5.1. G-Force Force Platform

The G-Force force platform integrates four load cells (Guangzhou, China, model YZC-516C) made of alloy steel, designed to measure force with high accuracy and stability. The system maintains reliable performance under standard environmental conditions and

tolerates moderate overloads, ensuring consistent and accurate strength measurements according to a previous internal validation study [21].

The load cells are distributed across four connectors located at each corner beneath a 50×27 cm metal plate with a thickness of 5 mm, while the upper surface of the plate is covered with anti-slip material. This configuration allows stable and reproducible positioning of a single measurement channel, ensuring proper alignment of the applied force with the sensitive axis of the load cells. Its simple design aims to facilitate usability, portability, and safety in both sports and laboratory settings (Figure 1).



Figure 1. Bottom view (a) and top view (b) of the G-Force force platform with YZC-516 load cell.

The load cell system was programmed to allow real-time force acquisition using load cells connected via USB-serial under the Modbus RTU protocol [22]. Data were sampled at an effective frequency of 100–120 Hz, with the capacity to record multiple channels in parallel. Prior to data collection, the platform was calibrated following procedures based on the static in situ calibration of force plates described by Hall et al. [23]. This calibration involved applying known static loads at predetermined positions on the platform to ensure the reproducibility and accuracy of the force signals. Data acquisition included polarity inversion and direct export in CSV format, while the graphical user interface (GUI) developed in Tkinter allowed real-time visualization of force–time curves and the automatic generation of a summary of key metrics [24].

This system automatically calculates the following parameters: maximum rate of force development (RFD), defined as the peak value of the first derivative of force with respect to time during the initial phase of contraction, reflecting the neuromuscular system’s ability to generate explosive force within very short time windows (<50 ms) [25]; RFD at specific intervals, calculated as the slope of the force–time curve over predetermined windows after contraction onset: 50, 100 and 150 ms [26]; and peak force, corresponding to the maximal force achieved during contractions, providing information on symmetry, consistency, and reproducibility of the measurement [27].

The G-Force platform records ground reaction force exclusively in the vertical axis, as measured by its uniaxial load cell. No horizontal shear components are captured. All force-time signals used for Peak Force and RFD analyses correspond to the vertical force vector.

Signal processing incorporated multiple digital filters—moving average, Savitzky–Golay, and second-order Butterworth—that effectively reduce noise while preserving the dynamic characteristics of the contraction (Figure 2).

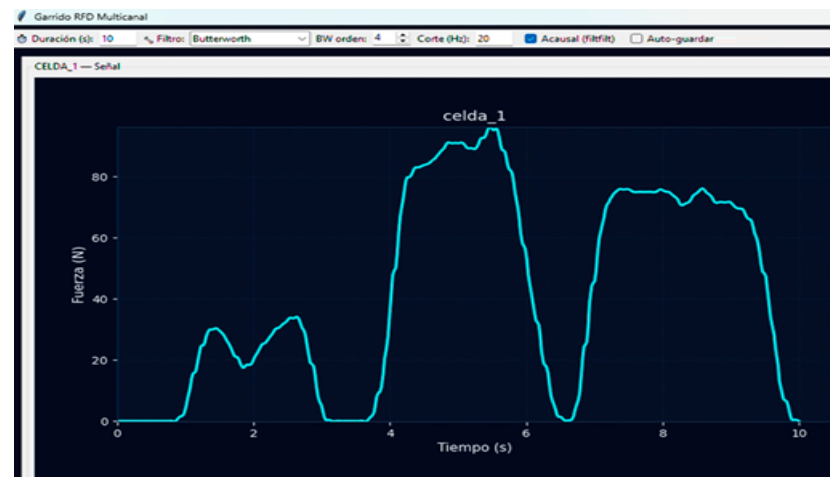


Figure 2. Software G-Force.

2.5.2. Valkyria Trainer Balance Force Platform

The force platform brand Ivolution (Rafaela, Argentina), VTB model consists of two force plates capable of recording forces in the vertical, longitudinal, and transverse directions, with a maximum capacity of 4000 N vertically and ± 500 N in the longitudinal and transverse directions [28]. Each plate integrates an internal signal acquisition and processing system, composed of a 64 MHz ARM Cortex M4F electronic board with 1 MB flash memory and 256 KB SRAM. Signals from each load cell are converted via an analog-to-digital converter and processed in real time by the platform's internal electronics [28].

2.6. Sociodemographic and Anthropometric Variables

Participants were assessed for age (years), height, and body weight, measured using a portable stadiometer (Cescorf, São Paulo, Brazil; maximum height 200 cm) and a digital scale (SECA model 803). Both instruments are considered valid according to the recommendations of the International Society for the Advancement of Kinanthropometry (ISAK) regarding measurement ranges and precision [29]. These measurements were also used to calculate body mass index (BMI) [30].

2.7. Exercise Protocol

2.7.1. Warm-Up

Participants performed a standardized 5 min warm-up, consisting of full-body stretches (flexion, extension, abduction, and adduction of the shoulders, hips, knees, and ankles), followed by joint mobility exercises. This was complemented with three repetitions of submaximal isometric contractions of hip abduction/adduction, as well as hip, knee, and ankle flexion and extension, progressively reaching approximately 50–70% of each participant's estimated maximal force to ensure familiarization with the movement and the load cell [31,32].

2.7.2. Isometric Posterior Lower Limb Muscle Test

For the test, participants were positioned supine on a flat surface with the hip and knee of the tested limb flexed at 90° , while maintaining a neutral lumbar spine. The non-tested leg remained extended on the floor to provide stability and prevent pelvic rotation. The heel of the tested limb was placed on the force platform, ensuring proper sagittal-plane alignment and minimizing compensatory movements such as pelvic lifting or hip rotation [33].

In this position, the maximal voluntary isometric contraction primarily targeted the posterior lower-limb musculature, particularly the hamstring muscle group, which generates force by pressing the heel downward against the platform. Secondary activation of surrounding hip stabilizers occurred to maintain joint alignment during the contraction. Participants performed a 3–5 s maximal isometric contraction following the evaluator's standardized verbal instructions [33].

Each limb was tested in two repetitions, separated by 30 s of rest to prevent fatigue. This interval was considered sufficient for the recovery of RFD since brief maximal isometric contractions primarily rely on the phosphagen energy system, which restores ATP and phosphocreatine within approximately 20–30 s under resting conditions. Consequently, the short duration and isometric nature of the task minimize metabolic fatigue and allow reliable repetition of maximal efforts. Previous studies have reported high reliability for isometric hip strength assessment in the 90/90 position, with intraclass correlation coefficients (ICC) above 0.90, supporting its consistency and accuracy in capturing hip muscle force production [34] (Figure 3).



Figure 3. Isometric posterior lower limb muscle test of the left leg (a) and right leg (b).

In the experimental setup, the platforms were placed on rigid storage boxes to match the height of the reference platform and ensure a consistent testing position. The boxes were made of high-density polymer and reinforced internally to prevent deformation or movement. Before data collection, the stability of the setup was verified through visual inspection and trial tests to confirm that no vibration or displacement occurred during the isometric contractions.

The measurements obtained from the G-Force and VTB platforms were not recorded simultaneously. Each participant performed two identical isometric tests—one with each platform—on the same day, under standardized conditions and with equivalent warm-up and rest periods. This procedure ensured comparable effort levels across trials, allowing for the assessment of validity between devices.

2.8. Biases

This study has several limitations and potential sources of bias inherent to its design [35,36]. First, there is a population bias, as only physically active young adults were considered, limiting the generalizability of the results to other age groups, fitness levels, or individuals with musculoskeletal or neuromuscular disorders. Second, familiarization and fatigue may have affected performance during the MVCs despite being included in the protocol, potentially generating learning effects or residual fatigue between trials, especially in the initial and final attempts of each session. Third, technical factors such as instrument calibration, potential signal noise, and operator-dependent variability could

have influenced data accuracy. Although both platforms were calibrated according to the manufacturers' specifications and data collection was performed by the same trained evaluator, these sources of error cannot be completely ruled out.

2.9. Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 27.0 for Windows (Armonk, NY, USA). Normality was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated with Levene's test. Descriptive statistics were reported as mean (X), standard deviation (SD), and 95% confidence interval (95% CI).

Intra-platform repeatability was determined by comparing the two repetitions of the isometric posterior lower limb muscle test performed for each leg on each platform. Repeatability was quantified using the Intraclass Correlation Coefficient (ICC; two-way mixed-effects model, absolute agreement, single measures) along with its 95% CI, the Standard Error of Measurement (SEM), the Minimum Detectable Change (MDC), and the Coefficient of Variation (CV%). The MDC was calculated as $1.96 \times \sqrt{2} \times \text{SEM}$, representing the smallest change that can be interpreted as a real difference beyond measurement error [37].

Inter-platform reliability was assessed by comparing values obtained from the G-Force and VTB platforms for each leg. ICC, SEM, MDC, and CV% were calculated to determine measurement stability and agreement between platforms. Bland–Altman analysis was additionally performed to identify systematic bias and 95% limits of agreement, considering only variables with high absolute and relative reliability [38].

Correlation between platforms was analyzed using the Pearson correlation coefficient, according to data normality, with effect size (r) reported to quantify the magnitude of the relationship. Values of r were interpreted as: trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5), high (0.5–0.7), very high (0.7–0.9), and nearly perfect (>0.9) [39]. ICC values were interpreted according to standard thresholds: poor (<0.5), moderate (0.5–0.75), good (0.75–0.9), and excellent (>0.9) [40,41]. CV was classified as good (<5%), moderate (5–10%), and poor (>10%) [41]. The significance level was set at $p < 0.05$ (two-tailed), and all analyses were performed with a 95% confidence interval.

3. Results

Table 1 shows the sociodemographic characteristics of the sample. The participants had a mean age of 23.67 ± 4.97 years, an average body weight of 76.78 ± 12.08 kg, and a mean height of 172.22 ± 9.56 cm, resulting in a mean body mass index (BMI) of 25.79 ± 3.02 kg/m².

Table 1. Sociodemographic characteristics of the analyzed sample (n = 9).

Variables	X ± SD	95% CI
Age (years)	23.67 ± 4.97	19.84 to 27.49
Weight (kg)	76.78 ± 12.08	67.49 to 86.06
Height (cm)	172.22 ± 9.56	164.87 to 179.57
BMI (kg/m ²)	25.79 ± 3.02	23.47 to 28.11

X: mean, SD: standard deviation, 95% CI: Confidence Interval with its corresponding 95%.

3.1. Intra-Platform Repeatability (G-Force) in the Isometric Posterior Lower Limb Muscle Test

Table 2 summarizes the reliability and variability indices obtained from the G-Force force platform during the isometric posterior lower limb muscle test.

Table 2. Intra-platform reliability of the G-Force force platform during the isometric posterior lower limb muscle test (n = 9).

Variables	Profile	Test (X $\pm$ SD)	Retest (X $\pm$ SD)	SEM	MDC	CV (%)	ICC (95% CI)
Peak Force (N)	Right	271.44 $\pm$ 82.02	274.95 $\pm$ 59.58	21.2	58.8	25.9	0.91 (0.65 to 0.98)
	Left	264.01 $\pm$ 57.38	239.48 $\pm$ 66.44	26.1	72.3	22.6	0.86 (0.26 to 0.97)
RFD50 (N/s)	Right	627.72 $\pm$ 355.16	613.50 $\pm$ 275.37	99.6	276	50.8	0.90 (0.63 to 0.98)
	Left	546.38 $\pm$ 285.04	489.52 $\pm$ 264.67	91.2	252.7	53.1	0.89 (0.61 to 0.97)
RFD100 (N/s)	Right	511.80 $\pm$ 291.71	480.80 $\pm$ 197.05	94.5	261.7	49.2	0.85 (0.48 to 0.96)
	Left	449.00 $\pm$ 236.52	397.51 $\pm$ 208.11	85.9	238	52.5	0.85 (0.50 to 0.96)
RFD150 (N/s)	Right	495.04 $\pm$ 286.99	489.98 $\pm$ 218.82	87.5	242.7	51.4	0.88 (0.54 to 0.97)
	Left	425.74 $\pm$ 217.50	375.03 $\pm$ 208.32	92.8	257.3	53.2	0.81 (0.40 to 0.95)

RFD: Rate of Force Development, X: mean, SD: standard deviation, CV: Coefficient of Variation, ICC: Intraclass Correlation Coefficient with its corresponding 95% CI, SEM: Standard Error of Measurement, MDC: Minimal detectable change.

Peak Force demonstrated excellent reliability, with ICC values of 0.91 for the Right limb and 0.86 for the Left, and relatively poor CVs (22–26%) across sessions. The MDC values for Peak Force were 58.8 N for the right limb and 72.3 N for the left limb, representing the minimum change that can be interpreted as a real difference beyond measurement error.

The RFD parameters exhibited moderate-to-high reliability (ICC = 0.81–0.90) but higher variability (CV $\approx$ 49–53%), reflecting the expected greater dispersion in measures derived from rapid force generation. MDC values ranged from 238 to 276 N/s, providing practical thresholds to detect meaningful changes in inter-trial RFD measurements. Specifically, RFD50, RFD100, and RFD150 showed ICC values ranging from 0.81 to 0.90, suggesting acceptable reproducibility despite moderate relative error, consistent with the inherent variability of explosive muscle actions.

Overall, these results indicate that the G-Force platform exhibits high repeatability for maximal isometric force measures and acceptable consistency for RFD metrics, supporting its suitability for assessing neuromuscular performance in physically active young adults. Including MDC values alongside ICC, SEM, and CV offers a more complete understanding of measurement error and system sensitivity, enhancing the interpretability of observed changes in both maximal and rapid force production.

3.2. Inter-Platform Reliability Between G-Force and Valkyria Trainer Balance (n = 9)

Table 3 presents the inter-platform reliability results between the G-Force and VTB systems during the isometric posterior lower limb muscle test.

Peak Force demonstrated moderate-to-good agreement between platforms, with ICC values of 0.75 for the right side and 0.77 for the left. The relatively poor CVs (20.5–25.7%) reflect substantial variability; nevertheless, MDC for Peak Force ranged from approximately 74–103 N, representing the minimum change that can be interpreted as a true difference beyond measurement error.

Table 3. Comparative reliability of the G-Force and VTB systems for isometric hip strength assessment in the isometric posterior lower limb muscle test (n = 9).

Variables	Profile	G-Force (X ± SD)	VTB (X ± SD)	SEM	MDC	CV (%)	ICC (95% CI)
Peak Force (N)	Right	271.44 ± 82.02	308.67 ± 67.23	37.31	103.4	25.73	0.75 (0.14 to 0.94)
	Left	264.01 ± 57.38	283.11 ± 54.64	26.86	74.4	20.47	0.77 (0.29 to 0.94)
RFD50 (N/s)	Right	627.72 ± 355.16	678.44 ± 260.38	153.88	426.3	47.13	0.75 (0.24 to 0.94)
	Left	546.38 ± 285.04	573.78 ± 281.06	116.70	323.5	50.54	0.83 (0.42 to 0.96)
RFD100 (N/s)	Right	511.80 ± 291.71	572.89 ± 328.60	111.83	309.6	57.19	0.87 (0.55 to 0.97)
	Left	449.00 ± 236.52	421.56 ± 198.26	84.60	234.4	48.57	0.75 (0.21 to 0.94)
RFD150 (N/s)	Right	495.04 ± 286.99	444.67 ± 264.72	123.90	343.5	57	0.75 (0.23 to 0.94)
	Left	425.74 ± 217.50	345.67 ± 200.61	92.18	255.3	52.89	0.80 (0.31 to 0.95)

RFD: Rate of Force Development, X: mean, SD: standard deviation, CV: Coefficient of Variation, ICC: Intraclass Correlation Coefficient with its corresponding 95% CI, SEM: Standard Error of Measurement, MDC: Minimal detectable change.

Regarding RFD, reliability indices ranged from 0.75 to 0.87 across different time intervals (50–150 ms), showing consistent but slightly lower agreement compared to intra-platform results. The highest correspondence was observed for RFD100 (ICC = 0.87), whereas early and late RFD phases (RFD50 and RFD150) exhibited moderate reliability (ICC = 0.75–0.80) and greater dispersion (CV ≈ 47–57%). The MDC for RFD variables ranged from approximately 234–426 N/s, providing a practical threshold to detect meaningful changes in inter-platform measurements.

Overall, the findings indicate that the G-Force platform provides measurements comparable to those obtained with the VTB, particularly for maximal force and general RFD patterns. Although the relatively high CVs (20.5–25.7%) reflect substantial variability, the similarity in ICC values suggests that both systems perform consistently under equivalent testing conditions. Furthermore, the inclusion of MDC values alongside ICC and CV offers a more comprehensive understanding of measurement error and system sensitivity, supporting the validity of the G-Force platform as a portable, low-cost alternative for assessing isometric strength and force–time characteristics in applied research and sports settings.

Table 4 summarizes the results of the Bland–Altman analysis for test–retest agreement of the G-Force platform. Overall, small mean biases and narrow 95% limits of agreement were observed across variables and sides, indicating good consistency between repeated trials. The lowest bias values were found for Peak Force (Right = 3.51 N; Left = 35.64 N), while slightly larger but still acceptable variations were seen for RFD parameters, particularly at shorter time windows. These findings support the reliability of the G-Force platform for measuring isometric force and RFD in both limbs.

Table 4. Bland–Altman analysis. The G-Force platform in test–retest (n = 9).

Variables	Profile	Bias	95% CI
Peak Force (N)	Right	−3.51	−66.11 to 59.09
	Left	35.64	−6.15 to 77.04
RFD50 (N/s)	Right	14.22	−275.68 to 304.12
	Left	56.86	−183.03 to 296.76
RFD100 (N/s)	Right	31	−246.10 to 308.09
	Left	51.49	−179.63 to 282.62
RFD150 (N/s)	Right	5.07	−255.58 to 265.71
	Left	50.72	−204.37 to 305.08

RFD: Rate of Force Development, Bias: Medium bias, 95% CI: Confidence Interval with its corresponding 95%.

Table 5 summarizes the results of the linear regression analyses, showing strong and statistically significant associations between the G-Force and VTB platforms for both peak force and RFD across both legs. The standardized regression coefficients (Beta) ranged from 0.74 to 0.88, indicating a strong positive relationship between the platforms, while the coefficient of determination (R^2) ranged from 0.55 to 0.77, reflecting the proportion of variance in G-Force measurements explained by VTB measurements. All regression slopes were statistically significant ($p < 0.05$), supporting the validity of the G-Force platform for assessing neuromuscular parameters in physically active young adults.

Table 5. Linear regression analysis between G-Force and VTB platforms in physically active young adults (n = 9).

Variables	Profile	R^2	Beta (Standardized)	<i>p</i> -Value
Peak Force (N)	Right	0.7	0.84	0.005
	Left	0.63	0.79	0.011
RFD50 (N/s)	Right	0.6	0.77	0.014
	Left	0.67	0.82	0.007
RFD100 (N/s)	Right	0.77	0.88	0.002
	Left	0.55	0.74	0.022
RFD150 (N/s)	Right	0.55	0.74	0.023
	Left	0.72	0.85	0.004

4. Discussion

The present study evaluated the reliability and validity of the G-Force force platform during isometric hip strength assessment in physically active young adults in Chile, a context where access to commercial, calibrated, low-cost dynamometers is limited. According to standard reproducibility classifications [40–42], Peak Force showed excellent intra-platform repeatability ($ICC = 0.86–0.91$) and moderate-to-good inter-platform reliability compared with the VTB system ($ICC = 0.75–0.77$). However, coefficients of variation were relatively high ($CV = 20–26\%$), exceeding commonly accepted thresholds ($<10–15\%$) for strength testing. This may be attributed to the limited number of maximal voluntary contractions per participant and inherent human performance variability [43]. Nevertheless, SEM values were relatively low for Peak Force (Right: 21.2 N; Left: 26.1 N), and the corresponding MDC values (Right: 58.8 N; Left: 72.3 N) provide a meaningful estimate

of the minimal change required to detect a real difference beyond measurement error, supporting the stability of intra-platform measurements.

From a physiological perspective, assessing isometric hip strength, particularly peak force and RFD, is essential for evaluating neuromuscular performance and functional integrity. The hip musculature, especially the gluteus maximus and medius, plays a pivotal role in pelvic stabilization and force generation during dynamic movements such as sprinting, cutting, and jumping. Isometric testing provides a controlled environment to measure MVC, minimizing variability from joint motion and offering a reliable index of muscle function [44]. RFD, in particular, reflects the neuromuscular system's ability to rapidly recruit and activate motor units, a key determinant of explosive strength and injury resilience [45]. Therefore, valid and reliable isometric strength assessments are indispensable in both performance monitoring and rehabilitation contexts. Demonstrating the physiological relevance and reproducibility of a low-cost device such as the G-Force platform, supports its implementation for objective monitoring of muscular adaptations and early detection of neuromuscular impairments.

Force platforms have been widely used as validation tools for both dynamic and static tests assessing muscle strength parameters [28,46,47]. Comparisons with previous studies reveal that the G-Force platform's performance aligns with findings from similar research on isometric force measurement tools [28]. Studies that have evaluated the reliability and validity of force platforms in sports science have reported similar levels of repeatability and agreement, supporting the robustness of the G-Force platform's measurements [28,46,47].

Bland–Altman analysis revealed small mean biases for Peak Force (Right: -3.51 N; Left: 35.64 N), indicating minimal systematic error and confirming the stability of this metric. Nonetheless, a general trend was observed for the G-Force platform to report slightly lower values than the VTB system, which may reflect differences in calibration, sensor sensitivity, or signal processing.

It is important to note that ICC values reflect the reliability or consistency of the measurements across trials and platforms, whereas the Bland–Altman bias and limits of agreement evaluate accuracy or agreement, indicating how closely the G-Force values approximate those of the reference VTB system. In contrast, RFD parameters (RFD50, RFD100, and RFD150) exhibited higher variability ($CV = 47\text{--}57\%$) and moderate reproducibility ($ICC = 0.75\text{--}0.87$). Given this extremely high variability, RFD lacks clinical and practical usefulness, and its interpretability is severely limited. Accordingly, RFD should be considered strictly exploratory and not a reliable outcome for monitoring, diagnostics, or decision-making in applied or clinical settings. The associated MDC values for RFD provide practical thresholds for detecting meaningful changes, although these values must be interpreted cautiously due to the inherent instability of the measure.

Among isometric tests, the isometric posterior lower limb muscle test and its variants across different planes and axes of movement have demonstrated validity in various populations [33,48,49]. Linear regression analyses between the G-Force and the VTB platform demonstrated strong and statistically significant associations for both Peak Force and RFD across limbs, with R^2 values ranging from 0.55 to 0.77 and standardized Beta coefficients from 0.74 to 0.88 ($p < 0.05$). These findings indicate that a substantial proportion of the variance in G-Force measurements can be explained by VTB measurements. However, despite these associations, the high variability of RFD precludes its practical application, and this parameter must not be interpreted as a reliable or actionable indicator of explosive neuromuscular capacity. The inclusion of MDC in the discussion highlights the minimal change that can be considered physiologically relevant, adding context for the interpretation of intra- and inter-platform variability.

From a practical perspective, conventional force platforms remain limited in accessibility due to their high cost, typically available only in universities and specialized laboratories. This limitation hinders routine monitoring of sports performance and early detection of strength deficits, potentially increasing the risk of injury in athletes [50]. Therefore, low-cost, portable platforms like G-Force offer a feasible alternative for field-based assessment. Furthermore, both Peak Force and RFD-derived parameters should be interpreted as complementary metrics to gain a comprehensive understanding of neuromuscular activation dynamics [51], with MDC values serving as a reference for meaningful changes over time. However, it must be emphasized that, due to its excessive variability, RFD should not be used as a standalone indicator of neuromuscular performance, nor should it be relied upon for individual monitoring or clinical decision-making. Therefore, its application is recommended preferably in longitudinal designs with intra-individual follow-up to detect clinically or practically relevant adaptations [52].

Several limitations should be acknowledged. First, the small sample size ($n = 9$) limits the statistical power and generalizability of the findings, and the observed effect sizes were small, indicating that the results should be interpreted with caution. Moreover, the inclusion of only young, physically active adults restricts the applicability of the findings to other populations such as older adults, clinical or rehabilitation groups, and competitive athletes. In addition, a major methodological limitation is that the two platforms were not used simultaneously. Since the force-time data were obtained in separate trials, the study cannot establish true concurrent validity; instead, it offers a comparison of repeated isometric contractions performed under similar conditions. Therefore, a more cautious interpretation regarding the agreement between devices is required.

Second, potential sensor saturation or resolution issues during the initial 50 ms of contraction may have affected the accuracy of RFD estimation, particularly considering the relatively low sampling rate (100–120 Hz) and the filtering parameters applied. Importantly, the sampling rate represents a substantial methodological weakness: RFD is highly sensitive to sampling frequency, and methodological guidelines recommend ≥ 500 Hz for accurate peak RFD estimation. At 100–120 Hz, RFD signals are unavoidably smoothed and underestimated, which likely contributed both to the high variability observed and to the lower absolute RFD values recorded by the G-Force platform. Thus, these limitations must be clearly acknowledged when interpreting device comparisons, as insufficient sampling frequency may partially explain the lower values obtained with G-Force. Third, minor deformation or instability of the platform due to the support configuration could not be entirely ruled out and may have contributed to measurement variability. Although the platform was securely fixed, future versions should incorporate more rigid support structures to minimize this potential source of error. Moreover, the physical setup—where the devices were mounted on storage boxes—may have introduced structural instability, dampening, or deformation, making our configuration a technical limitation that could have influenced force transmission and requiring that our results be interpreted with caution.

In addition, while verbal instructions were standardized and delivered consistently across all trials to ensure participant effort, residual inter-trial variability may still have influenced RFD outcomes. The high coefficients of variation ($CV > 20\%$) observed for RFD further emphasize the sensitivity of this parameter to methodological and neuromuscular factors. Together, these limitations reinforce that RFD should not be considered a stable or reliable output in this context.

Despite these limitations, the results support the use of the G-Force platform as a portable and cost-effective tool for assessing maximal isometric hip strength, whereas RFD metrics should be considered exploratory only and not suitable for routine monitoring until longitudinal studies are conducted to track intra-individual trends [50,51]. The inclusion

of MDC values enhances interpretability by allowing practitioners and researchers to determine whether observed changes in Peak Force or RFD represent true physiological adaptations rather than measurement error.

Future research should validate the G-Force system in larger and more heterogeneous samples, enabling stratified analyses by age, sex, training status, and other sociodemographic variables. Additionally, methodological refinements—such as increased sampling rates, improved signal filtering, and optimized familiarization protocols—are needed to reduce variability in explosive force metrics and to confirm the platform’s accuracy and reliability under different testing conditions [53–55].

5. Conclusions

The present study provides preliminary evidence that the G-Force force platform can serve as a feasible and moderately reliable tool for assessing maximal isometric hip strength in physically active young adults. Importantly, the absence of simultaneous measurements between platforms prevents establishing true concurrent validity; therefore, the findings should be interpreted as a device comparison rather than confirmation of concurrent agreement. Peak Force measurements demonstrated good intra-platform repeatability and represent the only outcome showing acceptable reliability and agreement with the VTB system, although the G-Force tended to yield slightly lower absolute values. In contrast, RFD parameters exhibited high variability and limited reproducibility, supporting their classification as secondary, exploratory metrics rather than reliable indicators of explosive force output.

In light of the small sample size and the major methodological limitation related to non-simultaneous testing, the conclusions should be interpreted cautiously and the results considered preliminary rather than definitive. Nevertheless, the G-Force platform shows promise as a portable and low-cost option for contexts with limited access to commercial dynamometers. Future research should validate these results in larger and more diverse populations, optimize sampling and signal-processing procedures, and evaluate the platform’s responsiveness to training or rehabilitation-induced changes in strength.

Author Contributions: Conceptualization, V.G.-O. and H.F.-B.; methodology, V.G.-O., H.F.-B. and R.A.-E.; software, V.G.-O.; validation, V.G.-O., H.F.-B., S.S.-G. and R.A.-E.; formal analysis, V.G.-O., H.F.-B., R.A.-E., S.S.-G., Á.R.-V., M.Q., L.R.-V., J.L.-G., A.Ñ.-A., A.P.-C. and D.R.-G.; investigation, V.G.-O., H.F.-B., R.A.-E., S.S.-G., Á.R.-V., M.Q., L.R.-V., J.L.-G., A.Ñ.-A., A.P.-C. and D.R.-G.; data curation, V.G.-O., H.F.-B. and S.S.-G. writing—original draft preparation, V.G.-O., H.F.-B., R.A.-E., S.S.-G., Á.R.-V., M.Q., L.R.-V., J.L.-G., A.Ñ.-A., A.P.-C. and D.R.-G.; writing—review and editing, V.G.-O., H.F.-B., R.A.-E., S.S.-G., Á.R.-V., M.Q., L.R.-V., J.L.-G., A.Ñ.-A., A.P.-C. and D.R.-G.; visualization, V.G.-O., H.F.-B., R.A.-E., S.S.-G., Á.R.-V., M.Q., L.R.-V., J.L.-G., A.Ñ.-A., A.P.-C. and D.R.-G.; supervision, V.G.-O. and H.F.-B.; project administration, V.G.-O. and H.F.-B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Institutional Ethics Committee of the Central University of Chile (protocol Code: 106/2025; Approval date: 30 October 2025).

Informed Consent Statement: All participants provided written informed consent prior to inclusion, in compliance with the principles of the Declaration of Helsinki.

Data Availability Statement: The data from this article will be made available by the authors on reasonable request.

Acknowledgments: During the preparation of this manuscript, the authors used ChatGPT-5-turbo to improve the grammatical style. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

RFD	Rate of Force Development
MVCs	maximal voluntary contractions
VTB	Valkyria Trainer Balance platform
G-Force	G-Force platform

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