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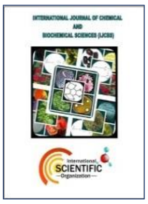

Between- and Within-session reliability and agreement of sprint Force-Velocity-Power profiling to report performance biomechanical outputs in physical education students: a pilot study

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Abstract

The mean objective of this study was to examine the reliability and agreement within- and between-session of the sprint Force-Velocity-Power profiling in untrained physical education youth students using a field testing method to report performance biomechanical outputs. An experimental study adopting a repeated-measure design was selected for this reason. One hundred and ten students (46 girls and 64 boys), age range (13.6±1.13 years old), participated in this study and completed 2 testing sessions with three trials of 30 m sprint running per session. The F-V-P profile was fitted by biomechanical modeling using spatiotemporal and position-time data. The intra-class correlation coefficient (ICC), standard error of measurement (SEM), coefficient of variation (CV), and the minimal detectable change (MDC) were used to evaluate the relative and absolute reliability. Whereas, the Bland–Altman (BA) plot with limits of agreement and maximal tolerable difference established before proceeding, was used for agreement test. A very large to nearly perfect relative reliability (ICC ranges 0.80 to 0.92) was noticed for most of inspected variables. Whereas, a moderate absolute reliability was noticed for the relative Maximal mechanical power HZT-Pmax (ICC= 0.8 and 4.4<CV <12.62%) and for the absolute Maximal mechanical power (ICC=0.87 and 4.28<CV<12.94%) and a high absolute reliability for the rest of variables (ICC≥0.80 with CV>10%). The graphical analysis of the Bland-Altman plots with limits of agreement and MDC bands clarified a clear trend for the data set and a good agreement within- and between-session scores. As a conclusion, the F-V-P profiling method could eventually be used for field-based evaluation in physical education lessons to assess anaerobic power and sprint performance in detail with stable performance intra- and inter-session testing in children and adolescents.

Keywords: Physical Education, Biomechanics, Force-Velocity Profile, Reliability, Agreement, Sprint Performance.

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1. Introduction

The reliability and agreement tests are widely confused in scientific literature [1–3] and often named Test-Retest. The reliability refers to the qualities of method or measurement instruments when assessing twice (or more) at different times. It's the ability of a test as well as any other instrument of measurement to distinguish between participants when administered repeatedly under identical conditions [1] . Stated differently, the reliability of a test is its ability to maintain the same ranking among participants when administered several times [3] it's a response to "How effectively, in spite of measurement error, does the method differentiate between participants?"[4]. There is certainly evidence that a measuring method or tool's usefulness and reliability are strongly related. In did, the testing method or the measurement tool cannot offer relevant data for comparing results from different subjects if it is unreliable. Whereas, agreement or reproducibility [5] refers to a test's or a measurement instrument's ability to produce precisely the same outcomes when administered repeatedly by the same participants under identical conditions, it requires that each participant expressed identical outcome during the retesting sessions, and reveals a kind of stability in measures upon time at same testing conditions [6] it's an analysis trying to answer the question about "How similar or close are the results of measurement that came from two different approaches or tests?"[1]. The agreement is crucial to remedy any deficiencies that prevent the distinction between real changes in the participant tested and random or systematic deviations driven on by the test's setup or conditions. In did, when an instrument's measurement error exceeds the inspected changes, the method or the device cannot be utilized to test and judge the improvements in performance [7].

We mention that a misconceptions regarding test-retest methods by confusing the reliability test to agreement ones, and we agree with *Berchtold* and colleagues [3] that the routine of adopting the same statistical methodology and the lack of statistical education are the mean raison of this misunderstanding. We highlight that a check for reliability and agreement is a crucial phase before proceeding in discriminate between subjects' performance and analyze it evolution across time to escape any risk of misinterpreting results.

Sprint-running is a key physical motor ability for a variety of sports and a determinant factor of performance in team competitions [8] and track-and-field sports [9]. It is also a good indicator of fitness [10] and a valid test of explosive force and anaerobic power expression [11]. Profiting from the evolution of the simulations of human running, the over-ground sprint Force-Velocity-Power profiling has increasingly become a popular method to evaluate and quantify the maximal sprint-running and report it subsequent biomechanical outputs underlining this performance in adults [12] [13] and in pediatric population [14] [15]. The estimations of force production, power output, and velocity are combined to provide a more complete measure of anaerobic performance wish themed important to improve training methods and manage injury process as reported by *Jiménez-Reyes et al.* [16]. The *Samozino* method of Force-Velocity-Power (F-V-P) profiling [17] using a macroscopic biomechanical model is an emerging approach that uses basic anthropometric data and a mono-exponential model of the velocity-time curve to obtain a continuous measure of power production (power–velocity relationship) and force production (force–velocity relationship) during a single maximum sprint [18]. The quantification of the underlying kinetics is made possible by the combination of straightforward data gathering techniques and macroscopic biomechanical models founded on Newton's fundamental laws of motion. In addition to sprint time, the method gives an overview of mechanical components of the sprint running performance [19] including maximal sprint running (MSS), the theoretical maximal horizontal force (HZT-F0), velocity (HZT-V0) and power (HZT-Pmax) in addition to the velocity wish the peak power was obtained (Vopt), the rate of mechanical force application efficiency as a percentage of the total ground reaction force (RF) and it decrement with increasing velocity (DRF), in addition to the force-velocity slope (SFV) serves as a standard for inter-individual comparison independently of their maximal power expression and to differentiate between deficit force and deficit velocity subjects profile [18]. Several test-retest was conducted to evaluate the reliability of the method to report reliable data in trained adults [17] [20] and trained children and adolescents [15] with mention that the test-retest was exerted to verify reliability without any mention to agreement test. To the best of our knowledge and to date of the study, this is the first study to test the reliability and agreement of sprint running Force-Velocity-Power profiling using *Samozino* field method [17] in untrained physical education students. We believe that a test-retest (reliability and agreement check) of the method could establish the approach as useful, valid and reliable in such pediatric population, and allow physical education teachers as well as coaches dealing with children and adolescents to benefit from the evolution of testing methods in field settings. The F-V-P profiling could be an effective evaluation tool enabling them with supplement information regarding biomechanics and kinetics underlining the anaerobic performance of sprint running. Therefore, the objective of this study was to verify between- and within-session reliability and agreement of the sprint Force-Velocity-Power profiling in physical education youth students using a field testing method and computed by biomechanical modeling.

2. Methods

2.1. Study Design

An experimental study adopting a repeated-measure design was selected to assess the reliability and agreement in the same testing session (within-session analysis) and across two spaced sessions (between-session analysis) of the sprint Force-Velocity-Power profiling in physical education youth students using a field testing method and computed by biomechanical modeling. All the testing sessions were performed on close climatic conditions (temperature = 20±2 °C and atmospheric pressure = 1020±60 hPa), in the same outdoor handball field and at the same span-time of the day (between 9h00 A.M and 12h00 A.M) to guarantee a maximum control over the testing conditions. Sufficient time recovery was allowed to participants in the intra-session sprint testing. Whereas, a 48-hour inter-sessions separated the two consecutive testing sessions.

2.2. Participants and Research Procedures

After receiving written consensus from parents or guardians and a verbal accord from students, a Musculoskeletal Health Questionnaire (MSK-HQ) was administered to all volunteered students to assess any local pain or physical impediment to practicing any physical activity, which was deemed an exclusion criterion. One hundred and ten students (46 girls and 64 boys), age range (13.6±1.13 years old), took part in this study. Anthropometric measurements: body mass in kilograms and body standing height in centimeters wiring lightly were collected for all participants, and body mass index BMI (kg.m^2) was calculated as body weight divided by the square of body standing height. Age and anthropometric data for participants are shown in (Table .1) as means ± standard deviations. The study was carried out in compliance with the Helsinki Declaration.

2.2.1. Maximal Sprint Testing

Participants were required to dress and shoe like they usual for physical education classes during the testing sessions and complete two maximal sprint tests during their regular physical education classes. The testing was tree consecutive 30m sprint run at session one (S1) and two consecutive 30m sprint run at session two (S2). A 3 to 5min recuperation time was allowed to participants for cardio-respiratory recovery between trails. Whereas, a 48-hour inter-sessions separated the two consecutive testing sessions (S1 and S2). Additionally, and before every field test, participants were told avoid to eat for at least an hour. Before every testing session, participants performed fifteen minutes standardized warm-up exercises without any static passive stretching [21] followed by two 20m sprint trails for familiarization with testing protocol. The participant stand and toke the ready position behind the start line, and after whistle start signal, he/she run at maximal speed in forward direction over the 30m linear distance. Teacher incite students to run at maximal velocity, do not slow down before crossing the end line and to encourage their mates when performing the test. As recommended by [22] [11], spatiotemporal data has been collected at five meters intervals with a high-speed video camera phone calibrated to record at 1180p resolution and sample at 300 frames per second.

2.2.2. Biomechanical modelling

The F-V-P profiles for all participants were biomechanically modeled using an open source custom-made Microsoft Excel spreadsheet (Microsoft Corporation 2016, USA) developed by JB. Morin and avalaible for download at [23]. The Microsoft Excel spreadsheet was made based on equations developed by *Samozino et al.* [17] and validated by Morin et all. [24], it uses anthropometric data of subject (i.e. body weight and height) and sprint position-time data (i.e., split times) in long with environmental conditions (i.e. temperature atmospheric pressure) to illustrate the quadratic Power-Velocity (P-V) and the linear Force-Velocity (F-V) relationships of a maximal sprint run [18]. The P-V and the F-V relationships explain the body's mechanical abilities during the all-out sprint running and provide a more comprehensive information about the performance of the runner. Sprint mechanical output variables (HZT-F0, HZT-Pmax, HZT-V0, RF, DRF, MSS, Vopt and FVslope) were subsequently calculated for each student and for every trail. A more thorough explanation of the experimental setup and a sprint mechanical outputs may be found in [11,19].

3. Statistical Analyses

All statistical treatments were conducted using SPSS Statistics Software (version 27, IBM, Armonk, NY, USA) with a significance level seated at p<5%. Descriptive statistics were reported as mean and standard deviation (M ± SD). The Shapiro-Wilks test was performed to test normality assumption and a Kolmogorov-Smirnov test to confirm equality of variance assumption for all variables. In did to standardize the data and eliminate bias, each variable that had been identified as non-parametric was log-transformed. To assess systematic changes in the examined parameters within- and between-sessions, a Student′s paired t-test was utilized.

3.1. Test for Reliability

The intra-class correlation coefficients (ICCs) for repeated measures was calculated using the 95% confidence intervals (CI) for the mean square values obtained from the ANOVA and used to assess relative reliability in line with previous suggestions for this type of research [15] whereas, the coefficient of variation (CV) was calculated to highlight the absolute reliability. Considering that reliability standards for three or more trials are not widely agreed upon, we used an open source custom-made Microsoft Excel spreadsheet developed by Hopkins [25] for Consecutive pairwise analysis of trials for reliability. Results were considered poor when (CV > 10% and ICC < 0.75) moderately reliable for (CV > 10% or ICC > 0.75) and highly reliable for (CV ≤10% and ICC ≥ 0.75) [20]. In addition, the equation (equa. 1) [26] was used to calculate The standard error of measurement (SEM). A SEM less than 10% was deemed acceptable for assessing absolute reliability and giving a clear indication of the test's degree of inaccuracy.

$$\textbf{SEM} = SD_{pd} * \sqrt{(1 - ICC)}. \qquad \textbf{(equa. 1)}$$

With SD_{pd}: between participant's pooled standard deviation.

3.2. Test for Agreement

To test within and between-sessions agreement of the method in evaluating and reporting the F-V-P profile and it subsequent mechanical outputs variables of the all-out over-ground sprint running we adopted the Bland–Altman plots or widely called the Bland–Altman Limits of Agreement (B-A LoA) [6] [4] coupled to the analysis of intra-class correlation coefficient and interpreted as recommended by *Simperinghamet al.* [20] with Pearson's correlation (r) correlation coefficient was performed to assess strength of the linear relationship between two trials [27] of the same session (T1 and T2) and the best trials of the two testing sessions (BT_{S1} and BT_{S2}). As opposed to [28] using random measurement error to determine the minimum level of change required to represent a "true" performance change, the minimal detectable change (MDC) at 95%CI was calculated using equation 2 (equa. 2) to illuminate typical fluctuations in sprint performance between testing sessions.

$$\textbf{MDC} = 1.96 * SEM * \sqrt{2} \qquad \textbf{(equa.2)}$$

Data are graphically displayed using a scatter plot (Bland–Altman plot) of differences versus average values obtained at the two trials measurements per participant using OriginPro Software (Version 2021, OriginLab Corporation, Northampton, MA, USA). The upper and lower limits of agreement (LoA) identified as the range that will probably contain 95% of the potential variations between two tests are calculated by equations 3 (equa. 3.a & 3.b) however bias (the mean differences) was calculated using equation 5 (equa.5) [6]. Whereas, visual evaluation of the Q-Q and the residual plots was used to check normality and homoscedasticity assumptions, respectively.

$$\textbf{\textit{Lower LoA}} = bias - (1.96 * SD \text{ of difference}) \qquad \textbf{(equa. 3.a)}$$
$$\textbf{\textit{Upper LoA}} = bias + (1.96 * SD \text{ of difference}) \qquad \textbf{(equa. 3.b)}$$

$$\textbf{\textit{bias}} = \frac{\Sigma_i d_i}{n} \qquad \textbf{(equa. 4)}$$

with n: number of participants and d_i: between and within trials difference by subject (i: 1,2,3… to 110).

4. Results

Descriptive statistics for students' age, anthropometric information and the sprint F-V-P profile mechanical outputs variables in the tree trials of the first session and the best performance of the second session are shown in (Table .1) and (Table .2). The statistical results of within- and between-sessions reliability for the sprint mechanical output variables are presented in (Table .3) and (Table .4) respectively. The test and retest (within and between sessions) revealed no noticeable variations in any of the examined variables (p-value ranging from 0.102 to 0.767).

Table .1 Students' age and anthropometric information.

	All (n= 110)		Girls (n= 46)		Boys (n= 64)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	13.60	1.13	13.17	0.84	13.90	1.22
Body weight (kg)	43.45	9.62	45.17	9.87	42.21	9.31
Body height (cm)	154.52	8.41	154.78	6.36	154.33	9.66
BMI (kg.m^2)	18.05	2.83	18.72	3.22	17.56	2.41

Table 2. The sprint mechanical outputs variables in the tree trials of the first session and the best performance of the second session.

	First Session (S1)			Second Session (S2)
	Trail 1	**Trail 2**	**Trail 3**	**Best Trail**
30m (sec)	6.39±0.66	6.21±0.71	6.29±0.54	6.27±0.65
HZT-F0 (N.kg^{-1})	6.50±1.12	6.49±1.15	6.60±1.28	6.56±1.43
HZT-V0 (m.s^{-1})	5.80±0.67	5.90±0.75	5.78±0.70	5.87±0.81
HZT-P$_{max}$ (W.kg^{-1})	9.41±1.80	9.58±2.11	9.53±2.04	9.55±2.08
F-V Slope (N.m. s^{-1}.kg^{-1})	-1.14±0.27	-1.12±0.26	-1.16±0.28	-1.15±0.34
RF max (%)	34.35±2.83	34.61±3.32	34.36±3.04	34.24±3.10
DRF (%)	-11.04±2.63	-10.80±2.54	-11.21±2.77	-11.08±3.39
V$_{opt}$ (m·s^{-1})	2.90±0.34	2.95±0.38	2.89±0.35	3.04±0.52
MSS (m.s^{-1})	5.61±0.60	5.70±0.68	5.59±0.62	5.67±0.76
Absolute Peak F0 (N)	280.88±71.83	280.59±75.75	284.92±77.35	284.07±86.91
Absolute Peak P (W)	406.40±110.30	415.34±127.28	411.00±115.74	412.95±122.12

*30m (sec): 30m sprint performance; HZT-F0 (N.kg^{-1}): relative Theoretical horizontal force; HZT-V0 (m.s^{-1}): relative theoretical velocity; HZT-P$_{max}$ (W/kg): relative Maximal mechanical power; RF$_{max}$ (%): maximal Ratio of force; DRF: Rate of decrease in RF with increasing running speed; F-V Slope (N.m. s^{-1}.kg^{-1}): linear F-V Curve Slope; MSS (m.s^{-1}): Maximal Sprint Speed; V$_{opt}$ (m·s^{-1}): Optimal Velocity; F0 (N): absolute peak force; P (W)absolute peak power. All variables are presented as (Mean ± SD).

Table 3. Within-session reliability statistics for the sprint mechanical outputs variables computed using the three trials of the first session.

	Overall Mean	95% CI		Change in Mean			SEM(%)	ICC	CV% (±SD)	Decision
		L. Bound	*U. Bound*	**T1-T2**	**T2-T3**	**T1-T3**				
30m (sec)	6.25	6.16	6.31	0.18	-0.08	0.10	0.22(3.69)	0.82	3.57±1.89	High R.
HZT-F0	6.22	6.14	6.30	0.10	0.02	0.12	0.37(5.88)	0.88	5.04±3.34	High R.
HZT-V0	5.58	5.52	5.64	-0.02	-0.10	-0.12	0.26(4.75)	0.82	4.83±2.61	High R.
HZT-P$_{max}$	8.70	8.54	8.86	0.12	-0.17	-0.05	0.74(8.50)	0.80	8.51±4.11	Moderate R.
FV Slope	-1.19	-1.21	-1.17	-0.02	-0.02	-0.04	0.09(-7.21)	0.91	-4.16±5.06	High R.
RF max (%)	33.22	32.96	33.48	0.02	-0.27	-0.25	1.17(3.52)	0.82	3.60±1.74	High R.
DRF (%)	-11.51	-11.70	-11.31	0.17	-0.41	-0.24	0.89(-7.73)	0.90	-4.36±4.89	High R.
V$_{opt}$	5.41	5.35	5.46	0.02	-0.11	-0.09	0.25(4.59)	0.81	4.55±2.43	High R.
MSS	2.79	2.76	2.82	0.01	-0.06	-0.05	0.14(4.88)	0.81	4.83±2.61	High R.
F0 (N)	268.39	264.20	272.57	-4.03	4.33	0.30	19.11(7.12)	0.92	5.04±3.34	High R.
P (W)	375.82	367.85	383.79	-4.59	-4.35	-8.94	36.37(9.68)	0.87	8.6±4.32	Moderate R.

*T1, T2 and T3: trial 1, 2 and 3 respectively; L. Bound: lower bound; U. Bound: upper bound; 95% CI: confidence intervals; ICC: the inter-class correlation coefficient; SEM: the standard error of measurement; CV: the coefficient of variation. High R.: high reliability. Moderate R.: moderate reliability. Poor R.: poor reliability.

Table 4. Between-session reliability statistics for the sprint mechanical outputs variables computed using the best trial of the first and the second testing sessions.

	Overall Mean	**95% CI**		**Change in Mean**	**SEM(%)**	**ICC**	**CV% (±SD)**	**Decision**
		L. Bound	***U. Bound***	**BT_{S1}-BT_{S2}**				
30m (sec)	6.15	6.11	6.18	-0.06	0.16 (2.54)	0.91	2.20±0.92	High R.
HZT-F0	6.26	6.16	6.36	-0.03	0.46 (7.39)	0.83	5.81±4.63	High R.
HZT-V0	5.71	5.65	5.76	0.04	0.25 (4.39)	0.86	4.23±1.78	High R.
HZT-P_{max}	9.27	9.14	9.41	0.07	0.61 (6.56)	0.89	4.39±3.84	High R.
FV Slope	-1.21	-1.24	-1.18	0.02	0.14 (-11.98)	0.80	-8.88±6.26	Moderate R.
RF max (%)	34.03	33.83	34.22	0.43	0.88 (2.59)	0.91	1.76±1.54	High R.
DRF (%)	-11.68	-12.00	-11.37	0.24	1.43 (-12.24)	0.80	-9.37±8.02	Moderate R.
V_{opt}	2.85	2.81	2.89	-0.01	0.18 (6.42)	0.70	4.54±3.94	Moderate R.
MSS	5.52	5.47	5.58	0.03	0.25 (4.50)	0.83	3.88±2.17	High R.
F0 (N)	270.80	266.00	275.60	-2.09	21.91 (8.09)	0.91	5.81±4.63	High R.
P (W)	400.98	394.03	407.93	3.03	31.70 (7.90)	0.92	4.39±3.84	High R.

* BT_{S1}: best trial in the first testing session; BT_{S2}: best trial in the second testing session. L. Bound: lower bound; U. Bound: upper bound; 95% CI: confidence intervals; ICC: the inter-class correlation coefficient; SEM: the standard error of measurement; CV: the coefficient of variation. High R.: high reliability. Moderate R.: moderate reliability. Poor R.: poor reliability.

Table 5. Agreement results of within-session trials in measuring sprint mechanical outputs variables.

	Session 1 Best trial		**Session 1 Worst trial**		**Pearson's (*r*)**	**Paired t-test**		**95%CI *Upper LoA* and *Lower LoA***	**MDC**	**ICC**
	Mean	**SD**	**Mean**	**SD**		***t*-value**	***p*-value**			
30m (sec)	6.28	0.52	6.23	0.58	0.75**	1.444	0.151	(-0.71; 0.82)	0.631	0.79
HZT-F0	6.50	1.12	6.49	1.15	0.90**	0.371	0.710	(-0.98; 0.94)	1.04	0.84
HZT-V0	5.80	0.67	5.90	0.75	0.75**	-1.535	0.134	(-1.09; 0.88)	0.744	0.78
HZT-Pmax	9.41	1.80	9.58	2.11	0.77**	-1.330	0.185	(-2.80; 2.46)	2.25	0.79
FV Slope	-1.14	0.27	-1.12	0.26	0.94**	1.927	0.268	(-0.19; 0.14)	0.233	0.89
MSS	5.61	0.60	5.70	0.68	0.74**	-2.087	0.198	(-0.98; 0.80)	0.689	0.76

*MDC: Minimal Detectable change; 95%CI: confidence intervals; ICC: the inter-class correlation coefficient; *r*: Pearson's correlation coefficient; **: significance at $p<0.001$; LoA: Limits of Agreement.

Table 6. Agreement results of between-sessions trials in measuring sprint mechanical outputs variables.

	Session 1 Best trial		**Session 2 Best trial**		**Pearson's (*r*)**	**Paired *t*-test**		**95%CI *Upper LoA* and *Lower LoA***	**MDC**	**ICC**
	Mean	**SD**	**Mean**	**SD**		***t*-value**	***p*-value**			
30m (sec)	6.23	0.58	6.27	0.56	0.81**	-1.307	0.193	(-0.72; 0.63)	0.432	0.91
HZT-F0	6.49	1.15	6.56	1.43	0.84**	-0.992	0.323	(-1.57; 1.42)	1.282	0.83
HZT-V0	5.90	0.75	5.87	0.81	0.74**	0.679	0.497	(-1.06; 1.13)	0.693	0.86
HZT-Pmax	9.58	2.11	9.55	2.08	0.84**	0.679	0.767	(-2.24; 2.30)	1.687	0.89
FV Slope	-1.12	0.26	-1.15	0.34	0.82**	1.645	0.102	(-0.35; 0.41)	0.401	0.80
MSS	5.67	0.76	5.70	0.68	0.73**	0.565	0.572	(-1.00; 1.06)	0.689	0.86

* MDC: Minimal Detectable change; 95%CI: confidence intervals; ICC: the inter-class correlation coefficient; *r*: Pearson's correlation coefficient; **: significance at $p<0.001$; LoA: Limits of Agreement.

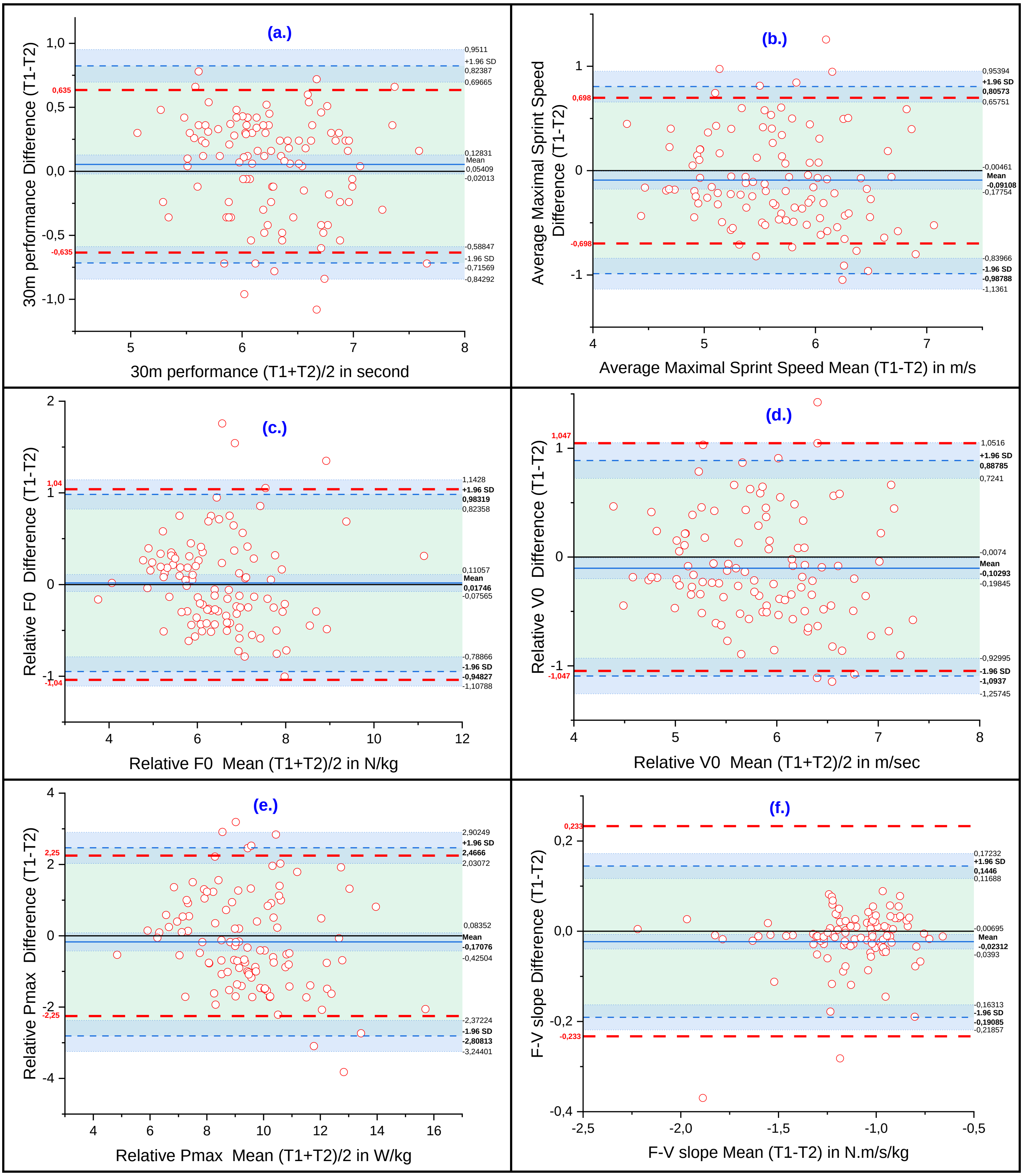

Figure 1. Within-session Bland-Altman plots of the mean values at x-axis and between trials (T1 and T2) difference of measurement at y-axis of sprint mechanical outputs: **a.** 30m performance (sec), **b.** Maximal Sprint Speed (m.s^{-1}), **c.** Relative theoretical horizontal Force (N.kg^{-1}), **d.** Relative theoretical horizontal Velocity (m.s^{-1}), **e.** Relative theoretical maximal horizontal Power (W.kg^{-1}), **f.** the Force-Velocity slope (N.m. s^{-1}.kg^{-1}). The bias in solid black line and 95% upper and lower LoA in dashed bleu lines. Bleu areas represents the 95%CI of LoA and bias. The negative and positive Minimal Detectable Changes (MDC) in red dashed lines.

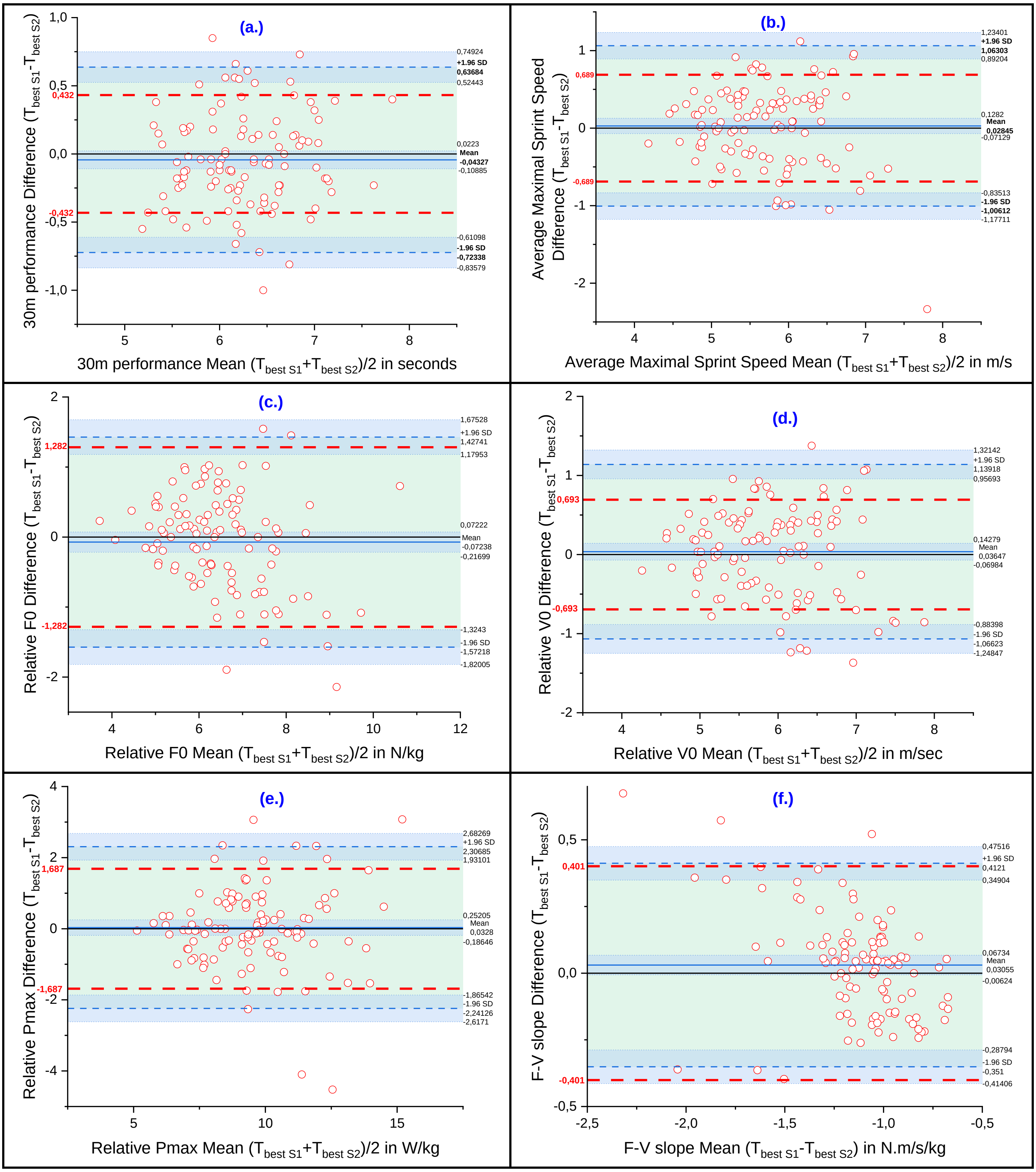

Figure 2. Between-sessions Bland-Altman plots of the mean values at x-axis and between best trials (BT_{S1} and BT_{S2}) difference of measurement at y-axis of sprint mechanical outputs: **a.** 30m performance (sec), **b.** Maximal Sprint Speed ($m.s^{-1}$), **c.** Relative theoretical horizontal force ($N.kg^{-1}$), **d.** Relative theoretical horizontal Velocity ($m.s^{-1}$), **e.** Relative theoretical maximal horizontal Power ($W.kg^{-1}$), **f.** the Force-Velocity slope ($N.m.\ s^{-1}.kg^{-1}$). The bias in solid black line and 95% upper and lower LoA in dashed bleu lines. Bleu areas represents the 95%CI of LoA and bias. The negative and positive Minimal Detectable Changes (MDC) in red dashed lines.

a. Results for Reliability testing

a.1. Results for Within-session Reliability

Almost all inspected variables presented a very large relative reliability (ICC ranges 0.80 to 0.88) except absolute theatrical horizontal Force F0 (ICC= 0.92), the rate of decrease in Ratio of force DRF (ICC= 0.90) and the F-V slope (ICC= 0.91) presented a nearly perfect relative reliability. However, the analysis of the absolute reliability has shown a high reliability for all variables (ICC ≥ 0.80 with CV > 10%) except for the relative Maximal mechanical power HZT-Pmax (ICC= 0.8 and 4.4 < CV < 12.62%) and for the absolute Maximal mechanical power P (ICC= 0.87 and 4.28 < CV < 12.94%) presented a moderate absolute reliability.

a.2. Results for Between-sessions Reliability

Similar to within-session, the analysis of the relative reliability has highlighted very large reliability (ICC ranges 0.80 to 0.89) for most variables and nearly perfect relative reliability for 30m sprint performance, for the maximal Ratio of force application (RF), for the absolute theoretical horizontal Force and for the absolute Maximal mechanical power (ICC≥ 0.91), whereas the Optimal Velocity (Vopt) presented a large relative reliability (ICC=0.70). Furthermore, the absolute reliability was high for most variables (ICC≥ 0.80 with CV> 10%). And moderately reliable for the force-velocity linear curve slope SFV (ICC=0.80 with 2.26<CV<15.14%), for the rate of decrease in Ratio of force DRF (ICC≥ 0.80 with -1.35<CV<-17.39%) and for the Optimal Velocity (Vopt) (ICC= 0.70 with CV< 10%).

b. Results for Agreement testing

The visual inspection of the Q-Q and residual plots verified that the assumptions of normality and homoscedasticity were met. The Bland-Altman plot was plotted with the limits of agreements (upper and lower LoA) and the ranges of acceptable difference (MDC) for within (Figure. 1) and between-sessions (Figure. 2) for the sprint mechanical outputs of the F-V-P profile.

b.1. *Results for Within-session Agreement*

The Figure 1 illustrate Bland-Altman plots of the mean values and between trials (Best trial and Worst trial) difference of measurements, whereas, the Table 5 report the statistical results of within-session trials agreement in measuring sprint mechanical outputs variables. The paired t-test didn’t detect any statistical significant differences between trials of the same session in all mechanical output variables (p>0.05). whereas the linear relation was strong to very strong between consecutive trials (r range 0.74 to 0.94) at p<0.001. In addition, intra-class correlation coefficient was ranging from 0.76 to 0.89 indicating a high within-session agreement. The limits of agreement are reported in Table 5 with the 95%CI for Upper and Lower LoA and the Minimal detectable change (MDC). The graphical representation (Figure 1.) shown that the Upper and Lower LoA exceeded the specified maximum allowable difference for all examined measurements and the difference of score measurements was less than the MDC in all variables with acceptable level of data distribution.

b.2. Results for Between-sessions Agreement

The Figure 2 and Table 6 report the statistical results of between-sessions trials (Best trial session 1 and Best trial session) agreement. No statistical significant differences between- sessions were reveled in all mechanical output variables (p>0.05). The linear correlation was strong between the two session trials (r range 0.73 to 0.84) at p<0.001. whereas, the intra-class correlation coefficient highlighted very large to nearly perfect agreement between session testing for the tested variables (ICC range 0.83 to 0.91). The Bland-Altman LoA plot clarified a clear trend for data set and a good agreement between-session scores.

5. Discussion:

The mean objective of this study was to verify within- and between-session reliability and agreement of the sprint Force-Velocity-Power profiling in physical education youth students using a field testing method, named widely in the literature as “*the Samozino method* “ [24],[17],[22]. The method was introduced to highlight the biomechanical aspect of the sprint performance and the combination of the force application at low and high velocity in power production during short distance over-ground sprint running using sample spatiotemporal data and computed by biomechanical modeling. We mention that numerous studies have inspected the reliability of the method and reported high reliability in high trained athletic adult population [15,24] and moderate to high reliability in adolescent athletes [15]. The reliability disparities may be explained by the inter-individual differences, as adult athletes with higher levels of training should be able to duplicate maximum bouts more reliably than athletes with lower levels of training. Currently, there are no studies that can be generalized to pediatric populations, since they are not miniature adults, and because running is still a fundamental movement skill that they are learning, which leads to more variable movement [29]. To the best of authors knowledge, this is the first study examining the reliability and agreement of the F-V-P profiling, sprint performance and the subsequent kinetics in untrained physical education students in field testing setting.

The Force-Velocity model in the present study offered reliable measurements of the maximal sprint running (MSS), the theoretical maximal horizontal force (HZT-F0), velocity (HZT-V0), power (HZT-Pmax), the force-velocity slope (SFV) the Optimal velocity (Vopt), the rate of mechanical force application efficiency (RF) and it decrement with increasing velocity (DRF) in school-going participants between trials of the same session and of two consecutive sessions. Similar finding was meted within-session test for reliability in children and adolescents using velocity data obtained by radar device [15] to fit the F-V-P model. Youth's affinity for sprint running was demonstrated by the comparable relative Maximal mechanical power (HZT-Pmax) outputs, which could potentially facilitate inter-study comparisons. Regardless of differences in approaches, in the current study HZT-Pmax presented higher coefficient of variation (8.51±4.11%) than those previously reported for running kinetics reliability researches [20]. In addition, the relative Theoretical horizontal force HZT-F0 were lesser (6.3 $N \cdot Kg^{-1}$ vs 7.7) than trained adolescent male sample studied by *Runacres* and colleagues [15] which might be explained as result of the level of physical activity difference [21], age disparity between the groups under study (13.6 ± 1.13 years old in this study vs 14.1 ± 1.0 for *Runacres* study) and the gender-based difference, in that the group included in this study was a mixed-gender sample, wish was not the case for *Runacres* et al. [15].

A low variability (CV<10%), a high relative reliability (ICC≥0.75) and a moderate to high absolute reliability (CV<10%; ICC>0.75) for the F-V-P Kinetic Variables confirms the reliability of the method in assisting in recognizing of smaller variations in sprinting performance and enable physical education teacher same as coaches by relevant feedback to provide their students and athletes with customized training/learning adapted continent [11] and addressing their kinetic lacks to enhance the over-all sprint performance. Analyzing statistically the trends of the variations across two measurements may be useful if the objective is to assess the agreement between the two. A strong to very strong linear correlation relation ($r \geq 0.73$ at $p<0.001$) was highlighted within- and between-session for inspected variables. However, the interpretation of this results as high level of agreement is inappropriate and often misleading [30] since there is always some degree of inaccuracy associated with measuring variables. Analyzing the variations across different observed variable magnitudes is crucial and compare it to "standard measurement" if any, or to the average of the two matched measurements (bias) seems to be an appropriate method in sports field [4]. The Bland-Altman plots (Figure 1. & 2.) provide a graphical analysis of this point and claim the decisions about the level of agreement between measures. Also, the introduction of the minimal detectable change (MDC) to ascertain the lowest degree of change required for illustrating a "real" performance change as opposed to typical fluctuations or random measurement error in sprint performance [31]. By combining the Bland-Altman method and the MDC, we initially determined the limits of maximum critical allowable variances (expected) based on analytically meaningful criteria and physiologically responses. The results showed low bias for most variables ($\bar{d}$ range 0.02 to 0.17) wish can be explained by the homogeneity of the sample tested in sprint abilities, and not significant since the line of equality is inside the mean difference's confidence interval. Regarding the sample size used in this study (n=110) the data map revealed the majority of the variations to be found between Upper-LoA and Lower-LoA. And most of the mean differences were within the MDC bands indicating a good level of agreement between trials of the same session (Figure 1.) and between-sessions (Figure 2.) testing.

6. Conclusions

The current results show that the "*Samozino method*" could eventually be used for field-based pediatric evaluation in physical education lessons to assess anaerobic power and sprint performance in detail with stable performance intra- and inter-session testing. The implementation of this method would improve our perception of the trainability of sprint running in this span-age and facilitate the targeting of kinetic weakness for a more effective motor-learning.

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