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ORIGINAL RESEARCH

Reliability analysis of static and dynamic plantar pressure measurements of children and youths with normal development

Análise de confiabilidade de medidas das pressões plantares estática e dinâmica de crianças e adolescentes com desenvolvimento normal

El análisis de la exactitud de las medidas de las presiones plantares estática y dinámica de niños y adolescentes con desarrollo normal

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ABSTRACT | Plantar pressure is used in clinical evaluation of the feet and informs about characteristics of the plantar load distribution during functional activity. Many evaluation instruments are used and its measurements properties must be tested. Test-retest reliability is a measure which informs about reproducibility. The objective of this study was to analyze test-retest reliability of maximum pressure measurements during static and dynamic in children and youths with normal development (ND). Eleven children and youths with ND of both sexes, with mean age between 6 and 17 years old, were evaluated twice in a weight bearing platform in orthostatic posture, barefooted and with their usual footwear, when the feet were positioned spontaneously (interrupted step) and the feet were aligned. Intraclass correlation coefficients (ICC) were analyzed (α=0.05). ICC were consistent for: anterior barefoot weight bearing (ICC=0.83) and posterior barefoot weight bearing (ICC=0.95) and with footwear (ICC=0.83), during the static analysis with interrupted step. They were also consistent for the variable static weight bearing of the right lower limb (ICC=0.86) and left lower limb (ICC=0.82) barefooted with interrupted step, and with footwear with the feet aligned (ICC=0.82). In the left lower limb analysis with footwear, the maximum pressure also showed a satisfactory result (ICC=0.85). Other variables showed ICC variation between 0.25 and 0.74, considered unsatisfactory. The conclusions are that test-retest ICC were considered excellent for some static conditions, and inconsistent in the dynamic evaluation.
Keywords | Child; Adolescent; Data Accuracy; Pressure; Foot.

RESUMO | A pressão plantar é utilizada na avaliação clínica do pé e informa características da distribuição de carga plantar em atividades funcionais. Diversos instrumentos de avaliação podem ser utilizados e devem ter as propriedades psicométricas analisadas. A confiabilidade teste-reteste é uma medida de reprodutibilidade. O objetivo deste estudo foi analisar a confiabilidade teste-reteste das medidas de pressão máxima na estática e dinâmica de crianças e adolescentes com desenvolvimento normal (DN). Onze crianças e adolescentes com DN, de ambos os sexos, com idade entre 6 e 17 anos foram avaliados duas vezes, em uma plataforma sensível à pressão plantar em ortostatismo, com e sem calçado usual, com os pés posicionados de forma livre (passo interrompido) e com os pés alinhados. Dados dinâmicos foram obtidos pela caminhada sobre a plataforma com e sem calçado. Coeficientes de correlação intraclasse (CCI) foram analisados (α=0,05). Os CCI foram consistentes para: descarga de peso (DP) anterior calçado (CCI=0,83) e

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DP posterior descalço (CCI=0,95) e calçado (CCI=0,83) durante a análise estática com o passo interrompido. Também foram consistentes para a variável DP estática do membro inferior (MI) direito (CCI=0,86) e esquerdo (CCI=0,82) com passo interrompido descalço e, com os pés alinhados, utilizando calçados (CCI=0,82). Na análise do MI esquerdo, com o uso de calçado, a variável pressão máxima também gerou resultado satisfatório (CCI=0,85). As demais variáveis apresentaram variação de CCI entre 0,25 e 0,74, consideradas insatisfatórias. Conclui-se que os valores de CCI foram considerados excelentes para algumas condições estáticas e inconsistentes na avaliação dinâmica.

Descritores | Criança; Adolescente; Confiabilidade dos Dados; Pé.

RESUMEN | Se emplea la presión plantar para examinar clínicamente el pie ya que ofrece información sobre las características de distribución del peso plantar en actividades funcionales. Hay varios instrumentos de evaluación que pueden ser utilizados y que se deben de analizar sus propiedades psicométricas. La exactitud prueba-reprueba es una medida de reproducibilidad. El propósito de este estudio es evaluar la exactitud prueba-reprueba de las medidas de presión plantar máxima en la estática y dinámica de niños y adolescentes con desarrollo normal (DN). Se evaluaron dos veces a once niños y adolescentes con DN, de ambos géneros, entre 6 y 17 años de edad, utilizando una plataforma sensible a la presión plantar en ortostatismo, con y sin los zapatos habituales, con los pies posicionados de manera libre (marcha interrumpida) y con los pies alienados. Se recolectaron datos dinámicos por intermedio de caminata sobre la plataforma con y sin zapatos. Se evaluaron los coeficientes de correlación intraclase –CCI (α=0,05). Los CCI fueron consistentes para: descarga del peso (DP) anterior del zapato (CCI=0,83) y DP posterior sin zapato (CCI=0,95) y con zapato (CCI=0,83) durante el análisis estático con la marcha interrumpida. También fueron consistentes para la variable DP estática del miembro inferior (MI) derecho (CCI=0,86) e izquierdo (CCI=0,82) con la marcha interrumpida sin zapato y, con los pies alienados, con el uso de zapatos (CCI=0,82). En el análisis del MI izquierdo, con el uso de zapato, la variable de la presión máxima también presentó un buen resultado (CCI=0,85). La CCI osciló en las demás variables entre 0,25 y 0,74, consideradas insatisfactorias. Se concluye que los valores de CCI fueron excelentes para algunas condiciones estáticas e inconsistentes en la evaluación dinámica.

Palabras clave | Niño; Adolescente; Exactitud de los Datos; Pie.

INTRODUCTION

Plantar pressure analysis is used for the clinical assessment of the foot and reports on characteristics of the plantar load distribution during the performance of functional activities[1]. The distribution of weight discharge and maximum pressure underfoot may be influenced by changes in the development of children and youths. These variables can be used to study the motor function of the lower limbs and thus contribute to the determination of more specific therapeutic objectives and to improve the quality of the treatment offered[2].

Literature reports different systems for assessing static plantar loading[2-9] and dynamics[1,5-8,10-19] in children and youths. However, information about test-retest reliability is infrequent[1,20]. This, in turn, weakens the extrapolation of the results, given the internal validity failure, generating doubt about the reliability of the evaluator in using a specific instrument. Therefore, the data obtained can be attributed to the actual characteristics of the sample or to the failure of the evaluation process[1].

Reliability is defined as a measure of consistency of data on relative levels of performance between raters, regardless of the absolute value of each rater's classification[21]. It is related to the consistency and precision of the results of the measurement process[22]. It is important to assess the reliability of the decisions taken by observers to know what measures are being taken[23].

The intraclass correlation coefficient (ICC) is the statistical tool most commonly used to measure the reliability of measures[23]. It is suitable to measure the homogeneity of two or more quantities and is interpreted as the proportion of the total variability attributed to the measured object[23]. ICC consists of the number of times the evaluators agree, divided by the total number of evaluations and ranges from 0 to 100%[23].

The aim of the study was to analyze the test-retest reliability of the measurement of weight and maximum pressure obtained in orthostatic posture (static analysis) and during gait (dynamic analysis) in children and youths with normal development.

METHODOLOGY

Participants

In this methodological study were included children and youths with normal development, of both sexes, aged between six and 17 years, who did not perform bone and / or muscular surgery in the lower limbs in the last year and who were able to understand simple orders such as verbal commands to perform body adjustments by maintaining orthostatic posture or walking on the platform.

Volunteers and guardians were guided regarding the objectives and characteristics of this study and were asked to sign the Informed Consent Form and, when applicable, the authorization term for image use. The research project was approved by the Research Ethics Committee of Hospital Universitário of Universidade Federal de Juiz de Fora (UFJF), under opinion no. 1.402.580.

Demographic, Clinical and Anthropometric Data

The volunteers of this study were evaluated in a room of the Faculdade de Enfermagem of UFJF. Initially, anthropometric data and lower limb length were collected. The last variable was measured in the orthostatic posture, from the greater trochanter to the ground[24], by a trained evaluator with adequate test-retest reliability (ICC=0.93).

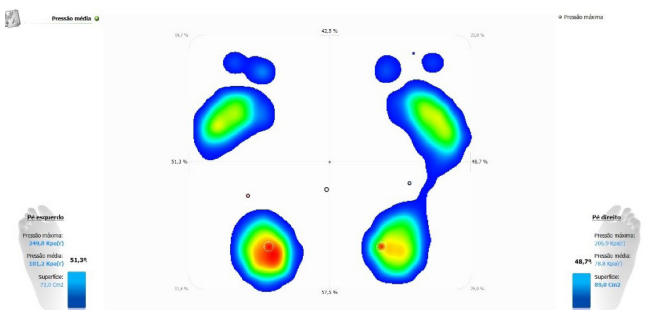
Instruments and procedures

Instrument

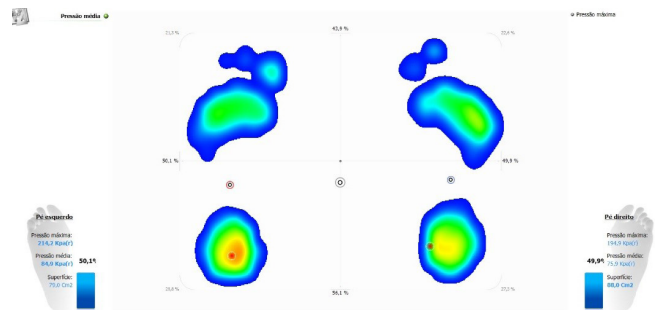
For the evaluation of the weight discharge, M.P.S. Platform® (Pressure Modular System – LorAnEngineering, Bologna, Italy) was used, which is a plantar pressure sensitive platform that captures information on gait and weight discharge. The platform was connected to a computer with the FootChecker® 4.0 software to analyze the variables of static weight discharge and dynamics of interest[25].

Procedures

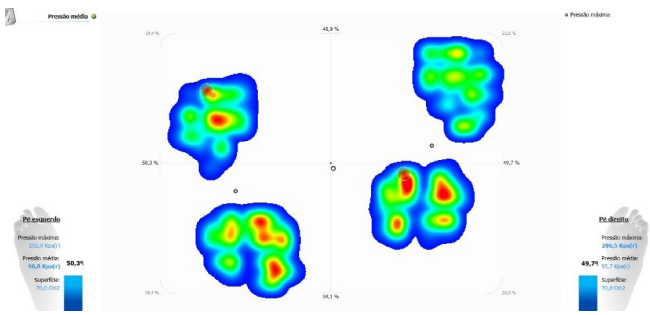
Volunteers were evaluated regarding static and dynamic weight discharge with and without the usual footwear. In addition, in the static collections, the volunteers were evaluated with their feet freely positioned (when they stopped walking).and with their feet aligned in relation to the acromion[24].



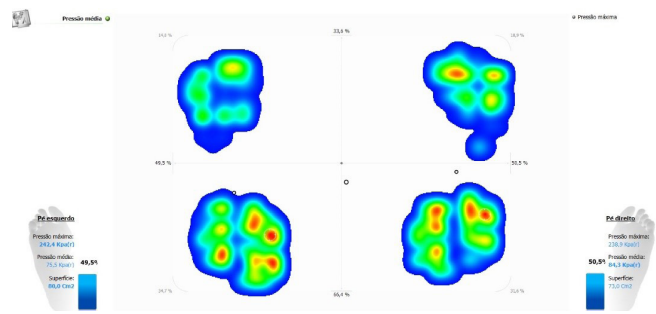
Barefoot with interrupted step



Barefoot with feet aligned in relation to the acromion



Usual footwear with interrupted step



Usual footwear with feet aligned in relation to the acromion

Figure 1. Weight discharge data captured by the platform during the static analysis with the step interrupted and with the feet aligned with the acromion with and without the use of usual footwear
Source: Authors (2016)

To evaluate the static weight discharge with interrupted step, volunteers were asked to walk naturally and stop at the beginning of the platform with the feet parallel (Figure 1). Then, the evaluator aligned the feet of the volunteers in relation to the acromion (Figure 1). In both positions, volunteers were asked to remain for 15 seconds on the platform, with horizontal gaze and upper limbs along the body.

In the analysis of dynamic weight discharge, to allow the initial acceleration and the terminal deceleration were made markings on the ground two meters before the edges of the platform, totaling six meters of total track. However, to ensure that the transition from the first step from the acceleration area to the platform and to that the deceleration area was smooth, a rubber with 0.5 mm thickness and the same color than the platform was affixed in such a way that the carpet became fully flat and did not demarcate transition areas (Figure 2).

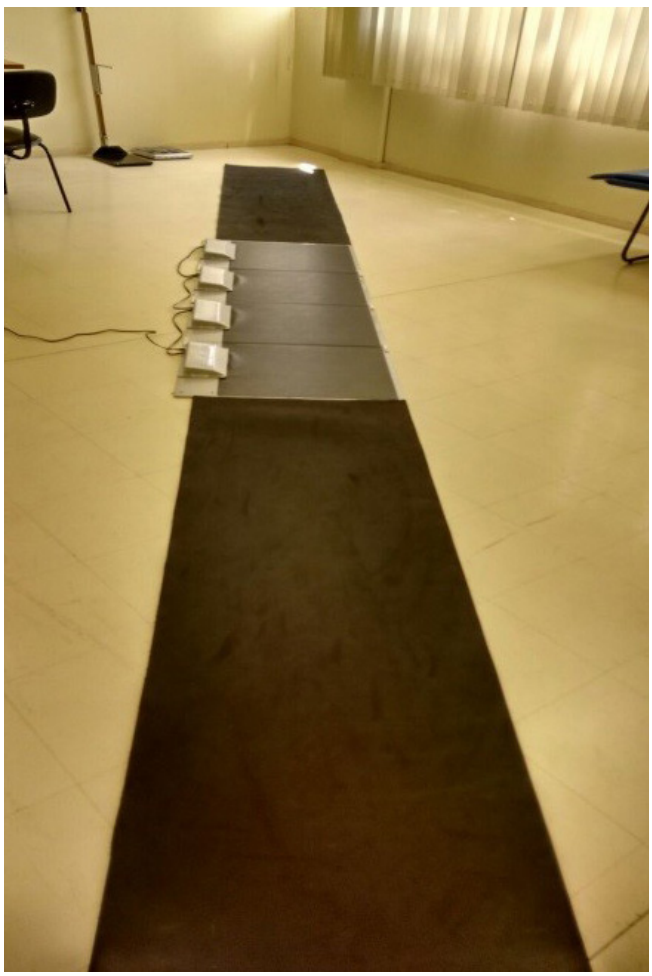


Figure 2. M.P.S. Platform® with rubberized mat affixed to the floor

Volunteers were asked to walk uninterruptedly, keeping their eyes horizontal. The procedure was repeated until totaling 30 meters per individual. Before that, a pretest with two replications was performed to familiarize the equipment.

Data were obtained in two distinct moments, with interval of not less than seven days, by two trained and experienced evaluators. Verbal commands and body adjustments were always performed by the first evaluator. Data were recorded and analyzed by a second evaluator.

Statistical analysis

Descriptive statistics of the anthropometric and demographic variables and the distribution tests of normality of Shapiro-Wilk of the outcome variables were performed. Next, we performed ICC tests in the statistical program SPSS 15.0 ($\alpha = 0.05$). Satisfactory ICCs equal to or greater than 75% were considered, which is the minimum acceptable agreement[26].

RESULTS

Sixteen children and/or youths participated in this study, but due to errors in the software, analyzable data were only collected from 11 volunteers. Descriptive information, with mean and standard deviation (SD) can be visualized in Table 1.

The test-retest analysis showed ICC values considered excellent for some test conditions in static analysis and inconsistent in others, especially in dynamic evaluation (ICC ≤ 0.71). The values were excellent for the variables of weight discharge of previous footwear (ICC=0.83) with the interrupted step and discharge of posterior weight with and without footwear (ICC=0.83, ICC=0.95, respectively), also in interrupted step. Variables of weight discharge in the right lower limb (RLL) (ICC=0.86) and left lower limb (LLL) (ICC = 0.82) were consistent when the volunteer was barefoot in the interrupted step. When using footwear, variables of weight discharge and maximum pressure were excellent (ICC=0,82) when feet were aligned to the acromion. In the analysis of the LLL, with the use of footwear, the maximum pressure variable also generated a satisfactory result (ICC=0.85) (Tables 2 and 3). Other variables presented a variation of ICC between 0.25 and 0.74, considered unsatisfactory.

Table 1. Demographic and anthropometric data (n=11)

Variables	Average ± Standard Deviation	Minimum-Maximum	
Age (years)	10.73±3.29	7.00–17.00	
Weight (Kilograms)	37.53±16.73	18.50–71.20	4 (100%)
Height (meters)	1.41±0.18	1.18–1.67	42 (100%)
BMI (kg/m2)	17.77±3.84	13.00–26.50	46 (100%)
Dysmetria of LL (cm)	0.18±0.34	0.00–1.00	

Caption: BMI: Body mass index; Kg = kilograms; M^2: square meters; LL: lower limbs; Cm: centimeters; Dysmetria: difference in length between limbs

Table 2. Test-retest of static analysis (n=11)

STATIC VARIABLES		FIRST ASSESSMENT Average ± SD	SME	SECOND ASSESSMENT Average ± SD	SME	ICC
Previous weight discharge						
Barefoot	IS	41.93±14.69	3.28	45.91±12.28	2.75	0.74
	AF	37.99±15.04	11.75	42.70±9.03	7.05	0.67
Footwear	IS	44.12±10.56	4.35	45.19±12.77	5.26	0.83*
	AF	43.52±12.04	9.41	41.15±14.06	5.60	0.39
Posterior weight discharge						
Barefoot	IS	58.07±14.69	3.28	54.09±12.28	2.75	0.95*
	AF	62.01±15.04	8.64	57.30±9.03	5.19	0.67
Footwear	IS	55.88±10.56	4.35	54.81±12.77	5.26	0.83*
	AF	56.48±12.04	9.41	55.21±7.17	5.60	0.39
Right lower limb barefoot						
IS	MP	189.75±32.75	25.15	174.14±17.69	13.59	0.41
	Weight discharge	49.77±4.28	1.60	52.67±3.63	1.36	0.86*
AF	MP	202.10±35.44	19.41	185.59±42.20	15.15	0.70
	Weight discharge	51.01±4.65	2.86	50.78±2.75	1.69	0.62
Left lower limb barefoot						
IS	MP	199.67±32.88	16.76	185.17±42.20	21.52	0.74
	Weight discharge	50.23±4.28	1.81	46.96±3.94	1.67	0.82*
AF	MP	219.30±35.69	40.37	186.37±28.81	32.59	−0.28**
	Weight discharge	48.99±4.65	2.86	49.22±2.75	1.69	0.62
Right lower limb footwear						
IS	MP	198.72±33.41	28.94	182.34±46.07	39.90	0.25
	Weight discharge	49.47±3.26	4.69	50,88±4.12	5.93	−1.07**
AF	MP	194.61±41.79	20.04	183,91±29.64	14.22	0.77**
	Weight discharge	51.86±5.64	2.39	51.22±4.36	1.85	0.82*
Left lower limb footwear						
IS	MP	196.97±41.79	21.31	192.95±59.44	30.31	0.74
	Weight discharge	50.53±3.26	4.69	49.12±4.12	5.93	−1.07**
AF	MP	188.86±46.35	17.95	179.26±38.46	14.90	0.85*
	Weight discharge	48.14±5.64	2.39	48.79±4.36	1.85	0.82*

Caption: SD: Standard Deviation; SME: Standard Measurement Error; ICC: Intraclass Correlation Coefficients; IS: Interrupted Step; AF: Aligned Feet; MP: Maximum Pressure
*ICC values considered excellent; ** Negative values due to the negative mean of variance between items that violate the precepts of the reliability model

Table 3. Test-retest of the dynamic analysis

DYNAMIC VARIABLES		FIRST ASSESSMENT Average ± SD	SME	SECOND ASSESSMENT Average ± SD	SME	ICC
Right lower limb						
Maximum pressure	Barefoot	396.57±30.06	42.72	407.23±84.07	119.48	0.71
	Footwear	459.63±102.55	66.46	382.82±88.70	57.48	0.58
Left lower limb						
Maximum pressure	Barefoot	408.40±34.60	19.26	384.62±45.99	25.60	0.69
	Footwear	441.08±71.72	41.82	419.09±86.11	50.21	0.66

Caption: SD: Standard Deviation; SME: Standard Measurement Error; ICC: Intraclass Correlation Coefficients

DISCUSSION

The aim of this study was to analyze the test-retest reliability of the measures of maximum pressure and discharge of weight in the feet during the orthostatic posture and in the gait of children and youths with normal development. The results showed inconsistent reliability values in some conditions and, satisfactorily, in others.

Values were consistent for the variables discharge of previous weight footwear and discharge of later weight with and without the use of footwear. Both measurements were obtained during the interrupted step. Still in the static, the results were satisfactory for the variable discharge of weight of the lower limbs with the step interrupted with the volunteers barefoot and, with feet aligned, with the use of footwear. The maximum pressure variable, obtained with the feet aligned and making use of footwear also generated a satisfactory result. The maximum weight and pressure discharge evaluated in percent, in each lower limb, are mirror variables and, therefore, the results were complementary.

ICC values for the anterior and posterior weight discharge variable with the feet aligned were not consistent. This may be due to an error generated by the evaluator during alignment or it may mean that the alignment of the feet to the acromion generated an internal disturbance in the individual who did not have the time to adjust. Thus, this change in the position of the feet maybe can cause new posture strategies to be elaborated, including synergies, patterns of joint movements, torques and contact force[27,28]. If the individual does not have previous experience with these specific adjustments, their instability will be greater in response to the external disturbance, affecting their postural control[128,29].

The weight discharge variable also generated inadequate ICC values when the feet were aligned in relation to the acromion, with the volunteers barefoot and in the interrupted step, making use of footwear. Although not always satisfactory, ICC values were better when the feet were aligned in relation to the acromion and volunteers were using the usual footwear. This may have occurred due to greater stability and greater distribution of foot pressures when the individual is wearing footwear. It is possible that, with bare feet, volunteers have greater joint instability at the ankles and therefore take longer to adjust their postural adjustments, causing the maximum pressure to have a punctual distribution on the soles of the feet, that is, more concentrated in certain anatomical points

On the other hand, still in the static analysis, ICC values were satisfactory only for the variable of maximum pressure in the lower limbs with the feet aligned by the acromion and barefoot. As suggested in other studies[1,2,9], the maximum pressure may travel through different regions of the feet (forefoot, midfoot and hindfoot) and may also be influenced by age. Thus, it might be appropriate and more reliable not only to evaluate the peak pressure, but also where it occurs, always with care to analyze the sample by age strata, due to the greater immaturity of postural control in younger children[1,2,9].

Dynamic analysis presented all ICC values classified as moderate. Rosenbaum et al[12]. analyzed children with typical development between four and 12 years of age, controlling speed during walking. They have shown that normal walking speed influences the characteristics of the load underfoot. Thus, it is possible that the great variability of this measure be a reflection of the lack of standardization of gait velocity, which may have generated ICC values below desirable. Nevertheless, it is known that there is an increase in joint stiffness with advancing age in healthy children, which increases the pressures under the metatarsals, generating constant variations in the distribution of the pressures observed during gait[10]. Consequently, it is possible that the variability of the sample age has determined the great variability in the maximum pressure measurements during gait, since the measurements performed on volunteers under 13 years tended to be more unstable[1,5].

At the same time, it should be pointed out that the acquisition of motor skills, mainly in the development process, can be explained by the perception and action of the repeated task[19], which may have occurred in the volunteers when walking on the platform for the second time. This can generate a learning effect that is a process of thinning and improving the detected responses. With this, the individual structures the available actions to improve and adjust postural adjustments[30].

This study had some limitations. We highlight the wide range of the age group of the volunteers evaluated and the lack of stratification of these individuals according to age. Another important aspect was the lack of speed control. Finally, it is possible that automatic closure errors of the software, which occurred on average in 40% of the data collection, influenced the children's progress, since, during the error, the volunteer was asked

to return to the beginning of the platform, which made the evaluation process tiring and time-consuming, and thus fatigue may have occurred.

In this study, we observed that the test-retest reliability of the weight-bearing variable between lower limbs and measurements obtained in the dynamic analysis was considered inadequate and this can occur by a variability of the measurement and not by the rater.

CONCLUSION

The test-retest reliability analysis of the variables maximum pressure and static weight discharge in children and youths with normal development presented adequate values for measurements with the interrupted step and without footwear and when the feet were aligned to the acromion, when using footwear. The measurements obtained in the dynamic analysis did not reach satisfactory levels of intra-examiner reliability.

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