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Trabajo Original

Valoración nutricional

Hand span influences optimal grip span in adolescents with Down syndrome

La envergadura de la mano determina la longitud del agarre óptimo en adolescentes con síndrome de Down

Ángel Matute-Llorente[1,2,3,4,5], Alejandro González-Agüero[1,2,3,4,5], Germán Vicente-Rodríguez[1,2,3,4,5] and José Antonio Casajús[1,2,3,4,5]

[1]GENUD (Growth, Exercise, Nutrition and Development) Research Group. Universidad de Zaragoza. Zaragoza, Spain. [2]Department of Physical Medicine and Nursing. Faculty of Health and Sport Sciences (FCSD). Universidad de Zaragoza. Huesca, Spain. [3]Departament of Physical Medicine and Nursing. Faculty of Health and Sport Sciences (FCSD). Instituto Agroalimentario de Aragón (IA2). Universidad de Zaragoza-CITA. Zaragoza, Spain. [4]Instituto de Investigación Sanitaria Aragón (IIS Aragón). Zaragoza, Spain. [5]Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y Nutrición (CIBERObn)

Abstract

Introduction: The hand grip strength test provides useful and reliable information about overall health. Different studies have investigated the optimal grip span for determining maximal hand grip strength in different populations such as adults, adolescents and children without disabilities.

Objective: To ascertain whether there is an optimal grip span for determining maximal hand grip strength in adolescents with Down syndrome (DS).

Methods: Twenty-seven right-handed youths with DS (seven females) aged 15.5 ± 3.6 years were evaluated in this methodological study. Each hand was randomly tested on ten times using five different grip spans, allowing one-minute rest between attempts. The hand span was measured from the tip of the thumb to the tip of the small finger with the hand widely opened. To confirm the usefulness of the optimal grip span, a new group of 15 adolescents with DS were recruited.

Results: An optimal grip span was identified for the dominant hand in adolescents with DS. The equation relating grip span as a function of dominant hand span in this group is formulated as follows: $y = 0.342x - 1.161$ cm ($r = 0.63$, $p < 0.05$). In the case of non-dominant hand, a tendency towards a linear association ($p = 0.058$) was found; the equation is formulated as follows: $y = 0{,}210x + 1.324$ cm.

Conclusion: It is important to standardize the procedure and increase reliability when measuring hand grip strength in DS population. The values stated in this study are recommended to assess hand grip strength in adolescents with Down syndrome.

Key words:

Intellectual disability. Dynamometry. Reliability. Standardization.

Resumen

Introducción: la fuerza isométrica máxima de antebrazo está relacionada con diferentes componentes de salud. Investigaciones previas han determinado la longitud de agarre óptima para el test de dinamometría manual tanto en adultos como en adolescentes y niños sin discapacidad.

Objetivo: determinar si existe una longitud de agarre óptima para el cálculo de la fuerza máxima de antebrazo mediante dinamometría manual en adolescentes con síndrome de Down (SD).

Métodos: en este estudio participaron 27 jóvenes con SD, diestros de mano y con una edad media de 15,5 ± 3,6 años. Ambas manos fueron evaluadas aleatoriamente diez veces usando cinco amplitudes de agarre diferentes y permitiendo un descanso de un minuto entre intentos. La envergadura de mano se midió desde la punta del primer al quinto dedo de la mano con la mano en su máxima amplitud. Para confirmar la utilidad del agarre óptimo establecido fueron reclutados otros 15 adolescentes con SD.

Resultados: se identificó una longitud de agarre óptima para la mano dominante de los adolescentes con SD. La ecuación que determina la longitud de agarre en función de la envergadura de la mano quedó definida como: $y = 0{,}342x - 1{,}161$ cm ($r = 0{,}63$, $p < 0{,}05$). En la mano no dominante se observó una tendencia ($p = 0.058$), siendo la fórmula $y = 0{,}210x + 1{,}324$ cm.

Conclusión: es importante estandarizar el procedimiento para aumentar la reproductibilidad del test de dinamometría manual cuando se mide la fuerza isométrica máxima del antebrazo en adolescentes con SD. Se recomienda usar los valores descritos en este artículo para el ajuste del dinamómetro cuando se realiza el test en adolescentes con SD.

Palabras clave:

Discapacidad intelectual. Dinamometría manual. Fiabilidad. Estandarización.

Ethical approval: The study was performed in accordance with the Declaration of Helsinki of 1975 (revised in Fortaleza, 2013) and was approved by the Research Ethics Committee (C.I. PI10/026). An informed consent was obtained from the parents of each participant as well as verbal assent from all participants.
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Correspondence:

José Antonio Casajús Mallén. Department of Physical Medicine and Nursing. GENUD Research group. Pedro Cerbuna, 12. 50009 Zaragoza, Spain
e-mail: joseant@unizar.es

INTRODUCTION

Muscular strength, one of the five components of health-related physical fitness, is associated with the ability to perform activities that require muscular force. The most commonly performed strength test for assessing this component is the measurement of grip strength with a hand grip dynamometer. The hand grip strength test provides useful and reliable information about overall health (1).

Several external factors are affecting results of the tests such as the angle of the shoulder, elbow, forearm, and wrist (2); the posture of the subject (3), and the grip span (4,5). The grip span is concretely the most influential among the previous factors because hand and palm lengths (6), and palm width (7) are highly related to the strength performed during the dynamometry.

Different studies have investigated the optimal grip span for determining maximal hand grip strength in different populations such as adults (8), adolescents (4) and children (5). Firstly, Ruiz et al. (4) found that there was an optimal grip span to measure hand grip strength in teenagers. Similar results were found in children some years later by España-Romero et al. (5). However, to our knowledge, no studies on this regard have focused on persons with Down syndrome (DS), despite the relevance that this might have. Muscle hypotonicity and low muscular strength (9) are clinical characteristics among persons with DS. Concerning their hands, individuals with DS have a smaller hand size compared with their counterparts without the condition (10). For these reasons, it would be expected that individuals with DS would have a unique optimal grip span, different from the ones described for non-disabled adolescents. Thus, the aims of the present study were: a) to ascertain whether there is an optimal grip span for determining the maximal hand grip strength in adolescents with DS; and b) to define the specific span values for optimal grip span in this particular population.

MATERIAL AND METHODS

This study has been performed following the methodological considerations published elsewhere (4,5,8).

PARTICIPANTS

Two different groups of adolescents with DS were involved in this research. The optimal grip span was determined from the first group (27 adolescents with DS). Then, the usefulness and the reliability of the calculated optimal grip span were confirmed in a new group of 15 adolescents with DS.

PROCEDURES

Measurement of hand span

Right and left hand spans, corresponding to the dominant and non-dominant hands, were measured with the hand widely opened, taking as reference from the tip of the thumb to the tip of the little finger. The precision of the measure was 0.1 cm, but the results of the hand span measurement were rounded to the nearest centimeter.

Measurement of handgrip strength

Hand grip strength was measured using a digital dynamometer (T.K.K. 5401 Grip-D; Takey, Tokyo, Japan), and the scores were recorded in kilograms (precision 0.1 kg). When performing the test, participants were instructed to maintain the standard bipedal position during the entire test with the shoulder in slight abduction, the elbow in complete extension, the forearm in pronation and the wrist in neutral position without touching any part of their body (11). Each subject performed (alternately with both hands) the test twice using different grip spans in random order, allowing a one-minute rest between the measurements (12). Latin square approach was used to avoid an ordering effect in the randomization of the testing. The used grip spans ranged from 3.5 to 7.0 cm. If the hand span was less than 20 cm, the broadest grip span was deleted; if the hand span was more than 20 cm, the thinnest grip span was deleted. For each hand, the best strength result for each grip span was selected.

Determination of optimal grip span

The kind of association relating grip span to hand grip strength was determined to establish the individual optimal grip span for each hand of each individual. The type of association could be linear, logarithmic, potential, quadratic, exponential, or polynomial. All functions were considered in the statistical analyses, and the most relevant was retained. The mathematical function was individually determined through the least-squares fit and graphically represented (Fig. 1).

Once the equation was defined, the optimal grip span was calculated as xIf´(x) = 0, where x corresponds to the optimal grip span (cm), and f´(x) is the handgrip strength (kg). In graphic terms, this corresponds with the maximum of the curves, as seen in figure 1. Only in six cases the association was quadratic (corresponding to a second-degree polynomial equation). For linear associations (n = 11), the optimal grip span was graphically determined. For those adolescents in whom there was no statistically significant association (n = 21 for the dominant hand and n = 17 for the non-dominant hand), the average strength of the chosen grip spans was retained.

Determination of the optimal grip span for a given hand span

The least-squares approach was used to establish the optimal grip span for a given hand span.

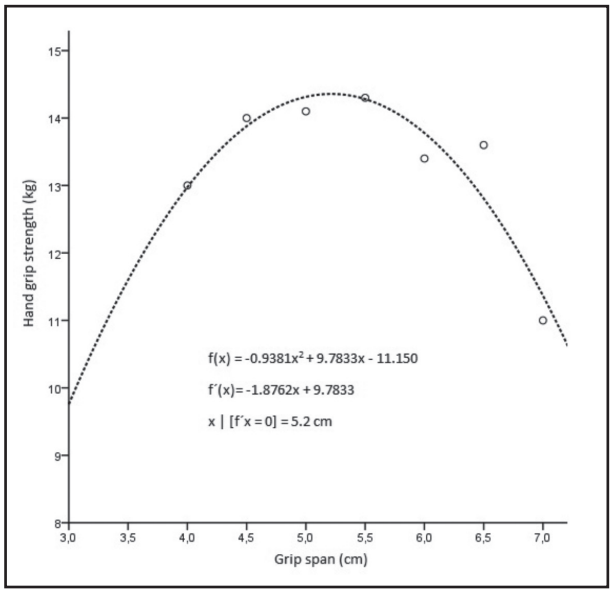

Figure 1.

Association relating grip span and hand grip strength for the dominant hand of an adolescent with DS. The maximum of the second-degree polynomial regression equation relating hand grip strength and grip span, f´(x), was the optimal grip span for each hand of each individual.

Usefulness and reliability of the optimal grip span

To confirm the usefulness of the optimal grip span when measuring hand grip strength in adolescents with DS, a new group of 15 adolescents with DS (ten boys, five girls) were recruited. The new group of adolescents performed the hand grip strength test at three grip spans using the Latin square design: 1 cm below the optimal grip span, optimal calculated grip span, and 1 cm above the optimal grip span. Each participant performed the test following the same protocol described above. For each hand, the best result at each grip span was retained. To confirm the reliability of measurements of hand grip strength at the optimal grip span, the same participants performed the test at the optimal grip span one hour later. All participants were watching a movie during this time.

STATISTICAL ANALYSES

The hand span, hand grip strength, and the optimal grip span obtained for each hand span by gender was compared with 1-way analysis of variances (ANOVA). Bivariate correlation was performed to evaluate the relationship between optimal grip span and hand span for each hand by gender. In the case of an association, the mathematical function defining the association was calculated through the least-squares fit. ANOVA for repeated measures was used to confirm the usefulness of measuring hand grip strength in three different conditions (optimal grip span, 1 cm below and above). The reliability coefficient of hand grip strength measured at the optimal grip span on two different occasions was compared through 1-way ANOVA for repeated measures, and correlated through parametric bivariate correlation analysis. The SPSS version 19.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Mean and standard deviations (SD) are given; otherwise, they are stated. The α error was fixed at 0.05.

RESULTS

The average hand span was 17.6 ± 1.4 cm for the dominant hand and 17.8 ± 1.5 cm for the non-dominant hand (n = 27). The optimal grip span was not significantly different between dominant and non-dominant hands (all $p > 0.05$) (Table I). Although no differences were found between hands, the optimal grip span and the span showed higher correlation with the dominant hand ($r = 0.660$, $p < 0.05$) than with the non-dominant hand ($r = 0.408$, $p < 0.05$), and the subsequent analyses were individually performed for each hand.

Table I. Optimal grip span determined in adolescents with Down syndrome (n = 27) for each hand span*

Hand span (cm)	Optimal grip span for sight hand (cm)	Optimal grip span for left hand (cm)	Optimal grip span† (cm)	p value‡
15	3.7 (0.4)	4.6 (1.0)	4.1	0.264
16	4.1 (0.2)	4.4 (0.7)	4.2	0.623
17	4.8 (0.7)	4.7 (0.8)	4.7	0.840
18	5.0 (0.5)	5.0 (0.5)	5.0	0.822
19	5.8 (0.2)	6.4 (0.2)	6.1	0.053
20	5.4 (0.9)	5.1 (1.0)	5.2	0.645

*Values are given in mean and standard deviation (SD). *The precision of the hand span measure was 0.5 cm and the value was rounded to the nearest centimetre. †Optimal grip span obtained from the mean of right- and left-hand optimal grip span. ‡Comparison between optimal grip span obtained with right hand* versus *optimal grip span obtained with left hand for each hand span.*

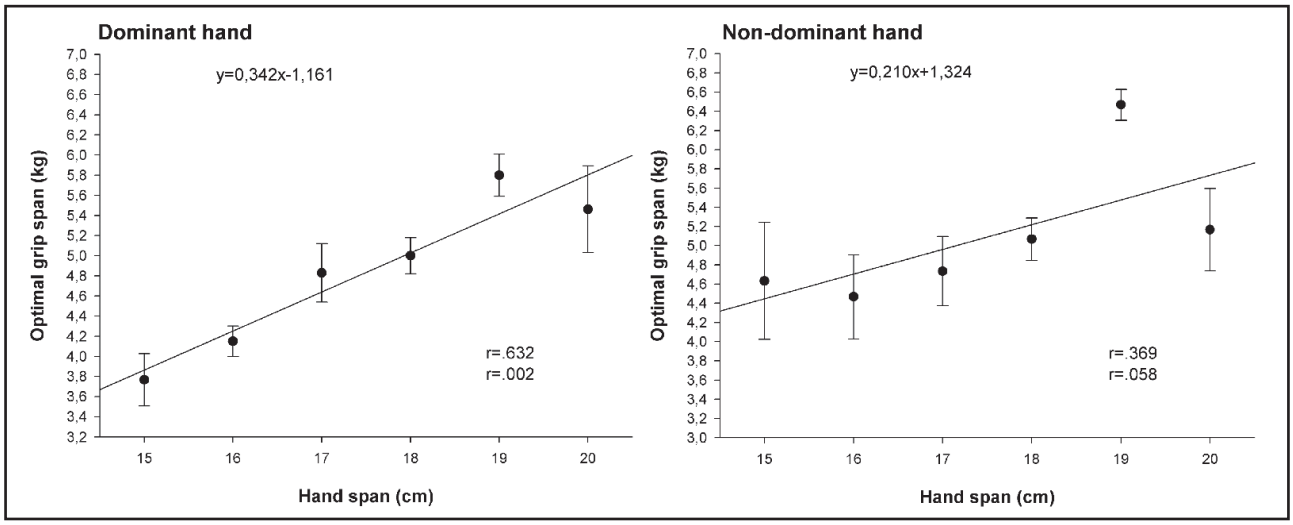

Figure 2.

Association between optimal grip span and hand span in adolescents with DS (n = 27). Values are means ± standard error of the mean.

Table II. Optimal grip span for each hand span calculated from the equations provided*

Hand size (cm)	Optimal grip span for the right hand (cm)	Optimal grip Span for the left hand (cm)	Optimal grip span† (cm)
13	3.3	4.1	3.7
13.5	3.5	4.2	3.9
14	3.6	4.3	4.0
14.5	3.8	4.4	4.1
15	4.0	4.5	4.3
15.5	4.1	4.6	4.4
16	4.3	4.7	4.5
16.5	4.5	4.8	4.7
17	4.7	4.9	4.8
17.5	4.8	5.0	4.9
18	5.0	5.1	5.1
18.5	5.2	5.2	5.2
19	5.3	5.3	5.3
19.5	5.5	5.4	5.5
20	5.7	5.5	5.6
20.5	5.9	5.6	5.8
21	6.0	5.7	5.9
21.5	6.2	5.8	6.0
22	6.4	5.9	6.2

**For the right hand y = 0.342x - 1.161 cm (r = 0.63, p < 0.05); for the left hand y = 0,210x + 1.324 cm (r = 0.369, p < 0.05); where x is the hand span (maximal width between thumb and little finger, with 0.5-cm precision), and y is the optimal grip span in centimetres. †Optimal grip span obtained from the mean of right- and left-hand optimal grip span.*

Hand span and optimal grip span showed a significant linear association in the studied adolescents with DS ($y = 0.273x + 0.141$; $r = 0.48$, $p < 0.05$), where *x* is the hand span (maximal width between first and fifth fingers), and *y* is the optimal grip span at which the dynamometer should be adjusted before testing. The equation relating grip span as a function of dominant hand span in this group is formulated as $y = 0.342x - 1.161$ cm ($r = 0.63$, $p < 0.05$). In the case of non-dominant hand, the equation is formulated as $y = 0,210x + 1.324$ cm ($r = 0.369$, $p > 0.05$), as seen in figure 2. The optimal grip spans for each hand span calculated from the equations provided are presented in table II. The hand grip strength obtained at the optimal grip span was significantly higher than the strength obtained when the grip was set 1 cm below the optimal grip span for the dominant hand ($p < 0.05$) (Fig. 3).

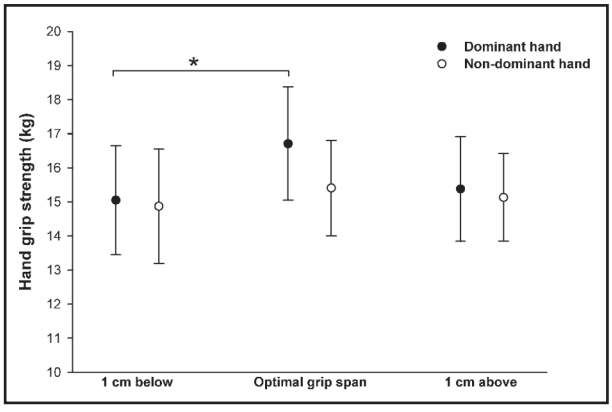

Figure 3.

Hand grip strength measured in dominant and non-dominant hands at optimal grip span, 1 cm below, and 1 cm above in adolescents with DS (n = 15). Values are means ± standard error of the mean. *p < 0.05 compared to 1 cm below.

The reliability coefficients for the optimal grip were 0.93 and 0.98 for dominant and non-dominant hands respectively. However, the one-way ANOVA for repeated measures showed statistical differences between test and retest ($p < 0.05$) for non-dominant hand and no differences for dominant hand ($p = 0.460$). A significant correlation between test and re-test for dominant ($r = 0.871$, $p < 0.01$) and non-dominant ($r = 0.967$, $p < 0.01$) hands was obtained at the optimal grip span.

DISCUSSION

The main finding of the present study is that there is an optimal grip span for the assessment of maximal strength in the dominant hand of adolescents with DS.

As previously recommended by Oppewal et al. (13), for adults with intellectual disabilities, both hands were tested in order to get a valid result of maximal strength.

The results of our study showed that the optimal grip span is more influenced by hand span in the dominant hand in comparison with the non-dominant one, which implies the need of adjusting the grip span of the dynamometer for each hand. For that reason, specific equations for each hand have been developed herein. The level of awareness, attention and their ability to cooperate are factors that make more difficult to measure hand grip strength in adolescents with intellectual disabilities than in those without. At the same time, they may be affecting our results and could explain the discrepancies between both hands. Nonetheless, our findings are in concordance with previous researches in which the optimal grip was influenced by hand span in non-disabled children (5), teenagers (4) and adults (8). Each population has some different physical characteristics; children have smaller hands than teenagers, who in their turn have smaller hands and lower hand grip strength compared with adults. For these reasons, it is possible to think that each specific group may need a specific optimal grip span to assess hand grip strength. This argument can be extrapolated to disabled-population such as adolescents with DS because they have some determined clinical characteristics as smaller hand spans or lower strength levels than those without (14).

The hand grip test has been shown to be a valid tool for measuring muscle strength in persons with some diseases and disabilities (15). This relatively cheap device is associated with many health-related parameters that are especially relevant in a population at risk such as adolescents with DS. On this regard, maximal muscular strength in the dominant arm has been demonstrated to be a good predictor to determine the risk of fracture in adolescents with DS (16). A recent study performed by Izquierdo-Gómez et al. (17) reported information about hand grip strength in adolescents with DS, showing lower hand grip strength compared to those without DS (14.9 *vs* 26.2 kg). It might be possible that their results were influenced for the use of the ALPHA health-related fitness test battery, which has been established for youth people without disabilities (18). In other populations with intellectual disabilities, similar results were reported by Kern et al. (19), finding that children with an autism spectrum disorder had significantly poorer hand grip strength than control children.

Muscle strength and tone in DS population may play an important role in activities of daily living. Positive improvements in grip strength can be found even after a single exercise session (20). As individuals with premature ageing, sarcopenia appears earlier in life and this is an issue for reduced functional abilities and quality of life for these persons. Several test can be used to measure specific strength, but none of them have been specifically designed for disabled adolescents, neither for those with DS. This study provides key information for therapists or sport scientist on how to better use the hand grip strength test in adolescents with intellectual disabilities.

This study is not exempt of limitations, being the main one the analysis of the sample as a whole, and not by gender. Our limited sample size, due to the intrinsic difficulty on getting a bigger number of participants in this limited age range and with the DS condition made it extremely hard to achieve a larger sample. On the other hand, the rigorous methodology and statistical analyses, together with the validation performed in a sample of 15 participants, ensure the feasibility of the obtained results.

To conclude, the specific grip values stated in this study for dominant hand span are recommended for assessing maximal hand grip strength in adolescents with DS.

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REFERENCES

1. Ortega FB, Silventoinen K, Tynelius P, Rasmussen F. Muscular strength in male adolescents and premature death: Cohort study of one million participants. BMJ 2012;345:e7279.
2. Su CY, Lin JH, Chien TH, Cheng KF, Sung YT. Grip strength in different positions of elbow and shoulder. Arch Phys Med Rehabil 1994;75(7):812-5.
3. Kato T, Miyamoto K, Shimizu K. Postural reaction during maximum grasping maneuvers using a hand dynamometer in healthy subjects. Gait Posture 2004;20(2):189-95.
4. Ruiz JR, España-Romero V, Ortega FB, Sjostrom M, Castillo MJ, Gutiérrez A. Hand span influences optimal grip span in male and female teenagers. J Hand Surg Am 2006;31(8):1367-72.
5. España-Romero V, Artero EG, Santaliestra-Pasias AM, Gutiérrez A, Castillo MJ, Ruiz JR. Hand span influences optimal grip span in boys and girls aged 6 to 12 years. J Hand Surg Am 2008;33(3):378-84.
6. Hager-Ross C, Rosblad B. Norms for grip strength in children aged 4-16 years. Acta Paediatr 2002;91(6):617-25.
7. Link L, Lukens S, Bush MA. Spherical grip strength in children 3 to 6 years of age. Am J Occup Ther 1995;49(4):318-26.
8. Ruiz-Ruiz J, Mesa JL, Gutiérrez A, Castillo MJ. Hand size influences optimal grip span in women but not in men. J Hand Surg Am 2002;27(5):897-901.
9. González-Agüero A, Ara I, Moreno LA, Vicente-Rodríguez G, Casajús JA. Fat and lean masses in youths with Down syndrome: Gender differences. Res Dev Disabil 2011;32(5):1685-93.

10. Chumlea WC, Malina RM, Rarick GL, Seefeldt VD. Communalities for rates of diaphyseal elongation of short bones of the hand of children with Down syndrome. Am J Phys Anthropol 1980;53(1):129-31.
11. España-Romero V, Ortega FB, Vicente-Rodríguez G, Artero EG, Rey JP, Ruiz JR. Elbow position affects handgrip strength in adolescents: Validity and reliability of Jamar, DynEx, and TKK dynamometers. J Strength Cond Res 2010;24(1):272-7.
12. Watanabe T, Owashi K, Kanauchi Y, Mura N, Takahara M, Ogino T. The short-term reliability of grip strength measurement and the effects of posture and grip span. J Hand Surg Am 2005;30(3):603-9.
13. Oppewal A, Hilgenkamp TI, Van Wijck R, Evenhuis HM. The effect of handedness on grip strength in older adults with intellectual disabilities. Res Dev Disabil 2013;34(5):1623-9
14. González-Agüero A, Vicente-Rodríguez G, Moreno LA, Guerra-Balic M, Ara I, Casajús JA. Health-related physical fitness in children and adolescents with Down syndrome and response to training. Scand J Med Sci Sports 2010;20(5):716-24.
15. Leal VO, Mafra D, Fouque D, Anjos LA. Use of handgrip strength in the assessment of the muscle function of chronic kidney disease patients on dialysis: A systematic review. Nephrol Dial Transplant 2011;26(4):1354-60.
16. Matute-Llorente A, González-Agüero A, Gómez-Cabello A, Gómez-Bruton A, Vicente-Rodríguez G, Casajus JA. Hand-grip strength and bone strength index at radius in adolescents with and without Down syndrome. VII Congreso Internacional de Ciencias del Deporte. Granada: Asociación Española de Ciencias del Deporte; 2012.
17. Izquierdo-Gómez R, Martínez-Gómez D, Tejero-González CM, Cabanas-Sánchez V, Ruiz Ruiz J, Veiga OL. Are poor physical fitness and obesity two features of the adolescent with Down syndrome? Nutr Hosp 2013;28(4):1348-51.
18. Ruiz JR, España Romero V, Castro Pinero J, Artero EG, Ortega FB, Cuenca García M, et al. ALPHA-fitness test battery: Health-related field-based fitness tests assessment in children and adolescents. Nutr Hosp 2011;26(6):1210-4.
19. Kern JK, Geier DA, Adams JB, Troutman MR, Davis GA, King PG, et al. Hand-grip strength in autism spectrum disorder compared with controls. J Strength Cond Res 2013;27(8):2277-81.
20. Chen CC, Ringenbach DR, Snow M. Treadmill walking effects on grip strength in young men with Down syndrome. Res Dev Disabil 2014;35(2):288-93.