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ORIGINAL ARTICLE

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A slightly adapted treadmill protocol for the determination of maximal oxygen uptake in adults with Down syndrome

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Abstract

Introduction: The VO_2 max test is the gold standard measure for aerobic fitness. A standardised treadmill protocol was developed years ago for individuals with Down syndrome but with variations in terms of starting speed, load increases and time spent at each stage. However, we realised that the most widely used protocol for adults with Down syndrome, trouble participants with high treadmill speeds. Consequently, the purpose of the current study was to determine whether an adapted protocol provided improved maximal test performance.

Method: Twelve adults (33 ± 6 years) randomly performed two variations of the standardised treadmill test.

Results: The protocol that added another incremental incline stage increase yielded a significant improvement in absolute and relative VO_2 peak, time to exhaustion, minute ventilation and heart rate max.

Conclusion: A treadmill protocol with the addition of an incremental incline stage allowed for a significant improvement in maximal test performance.

KEYWORDS
aerobic capacity, Down syndrome, heart rate maximum, minute ventilation, time to exhaustion, treadmill protocol, VO_2 max

1 | INTRODUCTION

The gold standard for the determination of aerobic capacity or cardiorespiratory fitness is a maximal oxygen uptake (VO_2 max) test (American College of Sports Medicine, 2013). Accurate determination of this variable is important as it is associated with cardiac disease, and future morbidity and mortality (Imboden et al., 2019; Kaminsky et al., 2022; Saghiv et al., 2020). The development of a protocol specific to the needs and abilities was necessitated as the aerobic capacity of individuals with Down syndrome is poor not only compared to the general population but also to age and gender matched individuals with intellectual disability without Down syndrome (Baynard et al., 2004, 2008; Pitetti & Fernhall, 2004). Moreover, individuals with Down syndrome suffer from low muscle strength, muscle hypotonia and ligamentous laxity which contributes to a reduced gait stability and negatively impacts their general mobility (Carmeli et al., 2002; Mendonca et al., 2010).

Pioneers in the field of intellectual disability and Down syndrome research, performed extensive research on this topic many years ago to develop suitable treadmill protocols for this population (Fernhall et al., 1990; Fernhall & Tymeson, 1987; Pitetti et al., 2000). They developed a treadmill protocol for individuals with intellectual disability having considered factors such as the type, feasibility, reliability and validity thereof. The study by Fernhall et al. (1990) included adolescents and adults with Down syndrome, but the study by Pitetti et al. (2000) included children and adolescents with intellectual disability, of which only two participants had Down syndrome. Many years

later, researchers are still using this protocol (Boer, 2018; Boer & Moss, 2016a, 2016b; Fernhall & Otterstetter, 2003; Guerra et al., 2003; Mendonca et al., 2011; Mendonca & Pereira, 2009). The protocol used starts with an initial velocity of 4 km/h at a 0% incline. Every 2 min the incline increases by 2.5% until an incline of 12.5% is reached. If the individual reaches this stage, the speed is increased by 1.6 km/h every minute thereafter. However, the protocol developed many years ago by Fernhall et al. (1990) did allow for variation in initial treadmill velocities, load increases and time spent at each stage. For example, some researchers that conduct maximal exercise testing for individuals with Down syndrome maintain the treadmill velocity and increase the incline until exhaustion (Casajus et al., 2012; Fernhall & Tymeson, 1987) whereas others increase the incline up to 12.5% and then increase the speed until exhaustion (Agiovlasitis et al., 2011; Baynard et al., 2004; Varela et al., 2001). Seron et al. (2014) performed a review on the different assessment protocols of maximum oxygen consumption in adolescents and children with Down syndrome and recommended the standard treadmill protocol developed by Fernhall et al. (1990) with its associated variations as the most suitable instrument for the assessment of cardiorespiratory fitness. They stipulated the importance of using validated and reliable treadmill protocols as four studies in their review neglected this important aspect.

We realised in two of our studies (Boer, 2018; Boer & Moss, 2016) that many individuals reach the 12.5% incline stage, but that further increases in speed (especially after 5.6 km/h) caused many individuals with Down syndrome to prematurely stop the test as they could not tolerate the increased velocity. Participants stopped the test despite reaching a respiratory exchange ratio (RER) value of 1.10 which is considered maximal in VO_2 peak testing (American Thoracic Society & American College of Chest Physicians, 2003; Baynard et al., 2004; Fernhall et al., 2001; Goulopoulou et al., 2006). The percentage of measured heart rate (HR) maximum compared to age predicted maximum HR as an indication of a maximal test could not be used as individuals with Down syndrome suffer from chronotropic incompetence (Fernhall et al., 2013). Also, the age predicted maximum HR equation developed specifically for individuals with Down syndrome (Fernhall et al., 2001) demonstrated significant differences between actual measured HR max and age predicted HR max with measurement bias and large limits of agreement (Boer, 2017). A study which also conducted maximal exercise testing on adults with intellectual disability, stated that the participants had difficulty with high treadmill speeds and performed their supramaximal cardiorespiratory testing using an incline of 15% (Weterings et al., 2017).

Despite meeting a RER of 1.10, we hypothesised that if an additional incremental incline stage (up to 15%) is included, further improvements in peak oxygen uptake and HR would accrue. Increases in incline beyond 15% was not considered as our pilot study demonstrated that participants reached for the handrails and fatigued in the locomotor muscles and not due to cardiorespiratory exhaustion. Therefore, the primary aim of the current study was to determine whether a slightly adapted treadmill protocol improved VO_2 peak for adults with Down syndrome. A secondary aim was to determine which variables contributed to the improvement in VO_2 peak if such an improvement was reported.

2 | METHODS

Twelve adults (eight men and four women; 33 years ±6.2) with Down syndrome from a live-in service provider for adults with intellectual disability volunteered and participated in the study. The legal guardians of the participants gave consent for participation in the study. The participants also signed an informed assent document which was written in 'easy read' format. Participants had to be between 18 and 45 years of age, and had to successfully complete the adapted physical activity readiness questionnaire (aPARQ). This meant that all questions had to be answered as 'no'. If 'yes' was answered at any question/s permission from the individual's physician had to be obtained. All participants lived at the service provider and had no cognitive or physical impairments that prevented them from completing all the exercise tests and training protocol. All participants were 'apparently healthy' and answered the aPARQ successfully. The study was approved by the Institutional Research Ethics Regulatory Committee of the University (00164-15-A9).

Participants attended at least four sessions, which were all based at the gymnasium on the premises of the live-in service provider for adults with intellectual disability. On the first visit, they were familiarised with testing equipment and procedures and visually demonstrated as to how a VO_2 peak test is performed (Fernhall et al., 1990). Information sheets, consent forms, adapted informed assent form and the adapted physical activity readiness questionnaire were handed out to individuals. Participants were given 7 days to decide whether they wanted to volunteer for the study, ask questions and complete the forms. If forms were correctly completed, they were asked to walk/run on the treadmill themselves with the respiratory collection system on the second visit (Fernhall et al., 1990). More sessions were conducted to individuals if deemed necessary. Five days later, body mass and height measurements were taken. Thereafter, six individuals performed one of the treadmill protocols in the morning, whereas the other six individuals performed the other treadmill protocol the next day (counterbalanced). Choice of treadmill protocol was fully randomised and the participants did not know that two differing protocols were being investigated. Ten days later, the same procedure was followed as in the third visit (Figure 1). This time, participants performed the protocol that they had not performed previously. The participants were not provided with feedback regarding respiratory, time, or heart rate measurements. They were only told when the treadmill incline or speed would increase. Standardised phrases of encouragement were used every minute as used in other intellectual disability studies (Nasuti et al., 2013; Duffels et al., 2009).

3 | TESTS

3.1 | Anthropometry

Body mass was determined with a calibrated electronic scale (Beurer, Ulm, Germany) to the nearest 0.1 kg. Participants wore light weight clothing, no shoes and emptied their bladders. Height was determined with a sliding steel stadiometer to the nearest

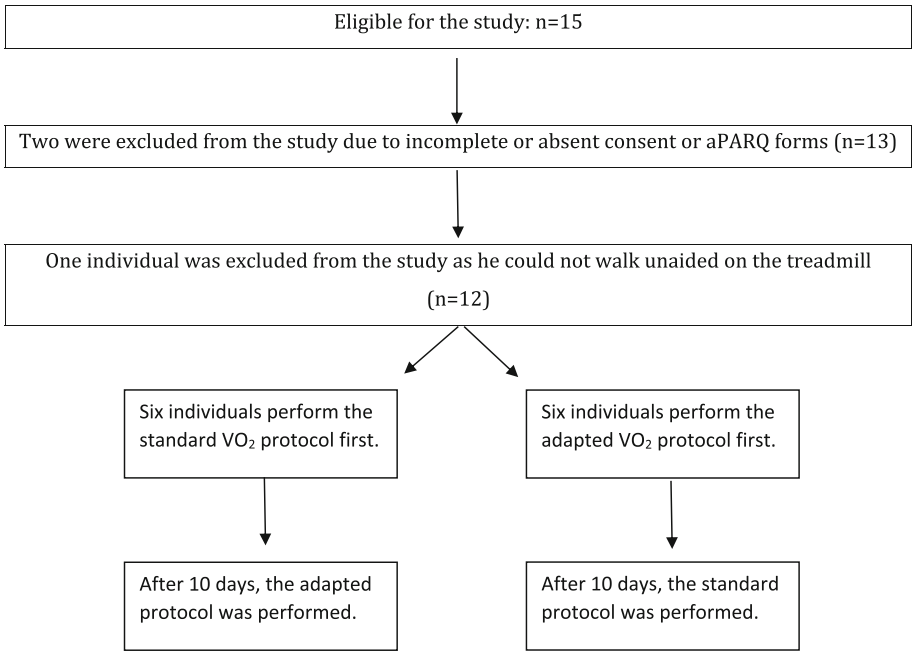

FIGURE 1 Flow diagram: Participants' flow diagram depicting the final sample and ordering of tests procedure during the trial.

0.1 cm (Siber-Hegner GPM, Switzerland). The participants stood with heels together and upper back, buttocks and heels against the wall. The head was placed in the Frankfurt plane. The measurement is then taken from the inferior aspect of the feet to the vertex of the skull. The height and weight was used to determine body mass index (BMI) in kg/m^2.

3.2 | Peak oxygen uptake test

The test was carried out on a motorised treadmill using the standardised protocol for adults with Down syndrome (Fernhall et al., 1990). This first protocol started at an initial velocity of 4 km/h at 0% incline. After every 2 min, the incline increased by 2.5% until an incline of 12.5% was reached. If the participant reached this stage, the speed was increased by 1.6 km/h every minute until exhaustion. The second protocol also started at an initial velocity of 4 km/h at 0% incline. After every 2 min, the incline increased by 2.5% until an incline of 15% was reached. If the participant reached this stage, the speed was increased by 1.6 km/h every minute until exhaustion.

Respiratory measurements and heart rate were performed using the metalyzer 3B system (Cortex, Leipzig, Germany). Heart rate recovery (HRR) was calculated during the first minute of recovery, immediately after exercise cessation. Minute ventilation (VE), oxygen consumption ($V0_2$) carbon dioxide production (VCO_2), heart and respiratory rate were measured breath by breath with mixed chamber analysis. The VO_2 peak was taken as the highest recorded measurement during the final 30 s of the tests with an RER greater than 1.10 (American Thoracic Society & American College of Chest Physicians, 2003; Baynard et al., 2004; Fernhall et al., 2001; Fernhall & Otterstetter, 2003; Goulopoulou et al., 2006; Nelson & Asplund, 2016). Data were filtered to 10- and 60-s averages. Participants were asked and continually encouraged to perform the test until maximal exhaustion as described by Varela et al. (2001). HRR was measured immediately after test cessation for 60 s with the participant standing stationary on the treadmill.

3.3 | Statistical analysis

Data were analysed with a commercially available statistical software programme (Statistical Package for the Social Sciences, SPSS 28.0, SPSS Chicago, IL, USA). Data were screened for normality and outliers by using descriptive statistics and the Shapiro–Wilk test statistic. Data are expressed as mean and standard deviation (*SD*). To evaluate differences between tests, a paired sample *T*-test was performed. To control for the possible confounding influence of test order, a one-way ANOVA was conducted. A multiple regression analysis was performed to determine which physiological variables contributed significantly to an increase in VO_2 peak (Enter method). The improvement of each predictor variable (difference in values for the adapted and standard protocol) was entered as the independent variables and the improvement in absolute VO_2 peak was entered as the dependent (response) variable. Only variables showing a significant correlation with the outcome variable was included in the multiple regression analysis. Pearson correlation analysis was conducted between the independent variables to determine whether multicollinearity existed. A *p*-value of less than .05 was considered significant.

4 | RESULTS

All 12 participants completed both treadmill protocols. No serious or adverse events occurred during any of the testing. All participants completed the VO_2 peak test until volitional exhaustion with a RER

value of greater than 1.10. The VO_2 peak values reached using the standard protocol (10- and 60-s filtering) was similar to previous studies conducted on individuals with DS (Boer & Moss, 2016; Mendonca et al., 2011; Varela et al., 2001).

Demographic variables are shown in Table 1. The descriptive information for all maximal metabolic exercise parameters are shown in Table 2. Ten- and sixty-second filtered data are provided for relative VO_2 peak, HR max and VE max. There was no significant difference in the change of all peak respiratory and heart rate measurements between those individuals who performed the standard protocol first (and thereafter the adapted protocol) compared to the individuals who did adapted protocol first (and thereafter the standard protocol). The results show that significant improvements are reported for the adapted protocol for relative and absolute time to exhaustion, VO_2 peak, HR max and VE max. The mean change of improvement for is similar for VO_2 peak (3.2 versus 3.3), HR max (4.8 versus 5.1) and VE max (7.3 versus 7.9) for 10- and 60-s data filtering techniques. Both filtering techniques showed significant findings (Table 2).

The figure illustrates the individual relative and absolute peak VO_2 (10-s filtering) of each participant for the standard and adapted protocol (Figure 2). The bolded lines indicate the mean values.

No significant correlations were found between the independent variables of the multiple regression analysis and only HR max demonstrated a significant correlation with the dependent variable. The multiple regression analysis revealed a significantly high $R^2 = 0.821$ to predict an improvement in VO_2 peak. The improvement in HR max significantly predicted an improvement in VO_2 peak with a standardised estimate of 0.91 (Table 3).

TABLE 1 Demographic variables ($n = 12$ adults with Down syndrome).

Variable	Mean (*SD*)	Minimum	Maximum
Age (yrs)	32.9 (6.2)	22	45
Height (cm)	157.2 (8.5)	143	173
Body mass (kg)	72.1 (9.4)	52	84
BMI	29.4 (4.8)	22	36

Abbreviations: BMI, Body mass index; yrs, years.

TABLE 2 Paired sample *T*-test for various physiological markers between the two protocols.

Variable	Standard protocol Mean (*SD*)	Adapted protocol Mean (*SD*)	Significance
TTE (s)	772.5 (85.8)	882.5 (84.3)	$p < .001$
VO_2 (L/min)	2.307 (0.511)	2.533 (0.604)	$p < .05$
VO_2 (mL/min/kg)[10 s][a]	32.2 (7.4)	35.4 (8.5)	$p < .01$
VO_2 (mL/min/kg)[60 s][a]	30.4 (7.4)	33.7 (8.0)	$p < .01$
HR max [10 s][a]	154.1 (12.0)	158.9 (9.6)	$p < .05$
HR max [60 s][b]	151.4 (11.9)	156.5 (9.4)	$p < .05$
VE (L/min) [10 s][a]	70.8 (20.8)	78.1 (17.7)	$p < .05$
VE (L/min) [60 s][b]	64.9 (20.5)	72.8 (18.8)	$p < .05$
RER [10 s][a]	1.21 (0.08)	1.17 (0.07)	$p = .18$
Heart rate recovery	24.2 (5.1)	23.6 (5.8)	$p = .62$

Abbreviations: TTE, time to exhaustion; VO_2, volume of oxygen; HR, heart rate; VE, minute ventilation; RER, respiratory exchange ratio; HRR, heart rate recovery.
[a]Data filtered to every 10-s.
[b]Data filtered to every 60-s.

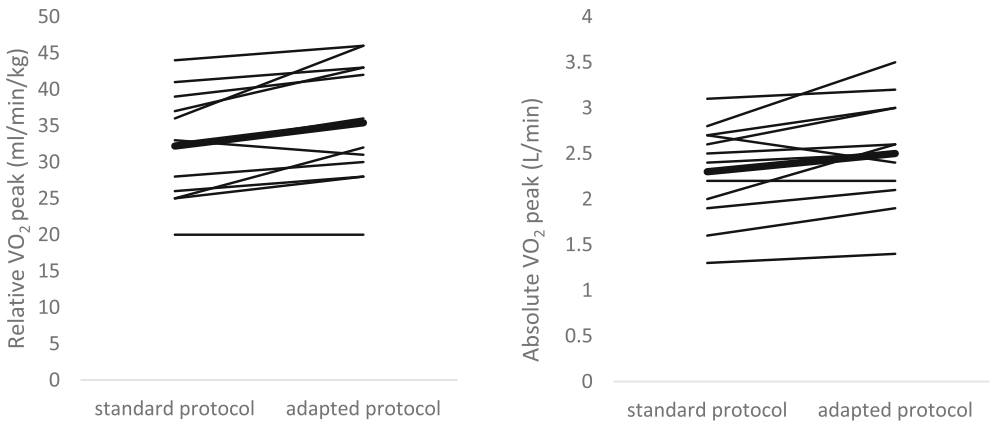

FIGURE 2 Graphical representation of each participant's relative and absolute peak VO_2 for the standard and adapted treadmill protocol (Mean: bolded line).

TABLE 3 Predictive linear model for an improvement in VO_2 peak (L/min).

Predictive variable	Parameter estimate	Standard error	*t*-Value	*p*-Value	Standardised estimate
Intercept	0.065	0.042	1.556	0.769	
HR max delta (bpm)	0.033	0.005	6.780	<0.001	0.906

Abbreviations: bpm, beats per minute; HR max, heart rate maximum.

5 | DISCUSSION

The primary purpose of the current study was to determine whether a slightly adapted treadmill protocol improved maximal physiological parameters in adults with Down syndrome. As hypothesised, another stage with a further incline of 2.5% yielded a significant increase in absolute and relative VO_2 peak, time to exhaustion, minute ventilation and HR maximum. This finding is also visually depicted individually for the 12 participants for absolute and relative VO_2 peak (Figure 2). Even though time to exhaustion and minute ventilation improved significantly, only the improvement in maximum HR was a significant contributor to an improvement in VO_2 peak. An improvement in maximum HR and cardiac output will allow more oxygenated blood to be pumped to the exercising muscles. These results were reported for both the 10- and 60-s data filtering techniques. Gas exchange as measured by the metabolic analyser is collected breath-by-breath. Raw data can be filtered to time averages, typically 10-, 20- or 60-s averages. Some previous studies conducted on adults with Down syndrome used a 10- or 20-s data filtering technique (Boer & Moss, 2016; Cowley et al., 2011; Mendonca et al., 2011; Mendonca & Pereira, 2009) whereas other studies used 60-s data filtering (Fernhall et al., 1990; Fernhall et al., 1997; Varela et al., 2001). As reported in the results section, the mean change of improvement was similar for VO_2 peak (3.2 versus 3.3), HR max (4.8 versus 5.1) and VE max (7.3 versus 7.9) for 10- and 60-s data filtering techniques and remained significant for both.

Adults with Down syndrome are born with many health-related complications and have very low physical and functional fitness when compared to adults in the general population and also to adults with intellectual disability without Down syndrome (Baynard et al., 2008; Foley & Killeen, 2019; Mendonca et al., 2011). These conditions are further exacerbated by a sedentary lifestyle, lack of exercise and obesity (Bertapelli et al., 2016; Diaz, 2020). Optimal aerobic capacity is important for adults with Down syndrome as a low VO_2 max has been associated with cardiovascular disease, increased body fat percentage and inability to perform everyday functional activities (Boer & Moss, 2016b; Cowley et al., 2010; González-Agüero et al., 2010; Salaun & Berthouze-Aranda, 2012). Fortunately, many research studies conducted on adults with Down syndrome have demonstrated significant improvements in aerobic capacity and functional fitness (Boer & Moss, 2016; Hardee & Fetters, 2017; Kerstiens & Green, 2015; Mendonca et al., 2011; Mendonca & Pereira, 2009). The accurate measurement of aerobic capacity is clinically important as maximal oxygen uptake is a key indicator of cardiometabolic health. Moreover, this variable is used for exercise prescription and for validity studies where field-based tests are compared to the gold standard VO_2 max test (Agiovlasitis et al., 2011; Boer & Moss, 2016b; Fernhall et al., 2000; Guerra et al., 2003). It is also used in prediction studies, such as the prediction of functional performance for adults with Down syndrome (Cowley et al., 2010; Terblanche & Boer, 2013) and the determination of maximum heart rate (Fernhall et al., 2001).

In two previous studies (Boer, 2018; Boer & Moss, 2016), we realised that many individuals felt uncomfortable with an increase in treadmill speed (especially beyond 5.6 km/h) and discontinued prematurely (even though RER values were in excess of 1.1). The additional incline stage allowed most adults with Down syndrome to walk/run for an extended period of time to exhaustion (11 of the 12 participants). However, we do not recommend the treadmill incline to increase beyond 15% as our pilot study indicated that most individuals could not tolerate the steep gradient and grasped for the handrails. There is a fine line between increasing treadmill speed and gradient and to what extent. Since adults with Down syndrome have low leg muscle strength (Croce et al., 1996) and Pitetti and Boneh (1995) reported a strong association between leg strength and aerobic capacity for adults with Down syndrome, a steeper treadmill incline (>15%) could cause the leg musculature to fatigue and as a consequence a peak VO_2 may not be reached if the test is terminated prematurely. It is also highly recommended (as suggested by Fernhall et al. (1990)) that adequate familiarisation sessions are performed as to prevent handrail holding and premature stoppage of maximal exercise tests. Many individuals with Down syndrome are not used to maximal or high intensity exercise and must be familiarised with the associated treadmill speeds, inclines and physiological effects thereof.

Seron et al. (2014) reviewed different assessment protocols to analyse peak oxygen consumption in children and adolescents with Down syndrome. Of the 11 protocols used to assess peak oxygen uptake, seven were variations of the standardised protocol (Agiovlasitis et al., 2011; Baynard et al., 2004, 2008; Casajus et al., 2012; Fernhall et al., 1996; Guerra et al., 2003; Varela et al., 2001) developed by Fernhall et al. (1990). Some of these studies had been validated (Baynard et al., 2004; Casajus et al., 2012; Fernhall et al., 1996; Varela et al., 2001) as indicated by Seron et al. (2014) It is clear from the results of the current study that certain versions of the standardised treadmill tests could yield more maximal results.

6 | CONCLUSION, LIMITATIONS AND FUTURE STUDIES

The use of standardised treadmill tests in adults with Down syndrome is crucial since these individuals have a unique build and

physical characteristics (Horvath et al., 2015; Terblanche & Boer, 2013). The results of the current study demonstrated that the use of an additional treadmill incline stage elicited significant increases in various physiological markers and time to exhaustion. A limitation of the current study is that the sample size is small. Consequently, further analysis to determine the effect of age, gender, body mass index and baseline fitness could not be explored. Additionally, although these results provide a statistical significance for a small sample, it does not translate to a clinical significance and thus should be interpreted with caution. The results of the current study cannot be generalised to those individuals with severe intellectual disability or those with concomitant physical impairments and future studies should explore the best suited protocol for these selected groups. The effect of level of intellectual disability could not be accounted for in the statistical section as this information is unknown for most people living with intellectual disability in South Africa. Moreover, the test–retest reliability for the adapted treadmill protocol remains to be determined. Future research should also determine the effect of increasing treadmill gradient indefinitely and maintaining the speed compared to the first protocol of the current study and with a larger sample size. However, our pilot study confirmed that treadmill inclines beyond 15% had a negative effect on maximal exercise performance. Future research should also further explore the optimal treadmill protocol in adults with Down syndrome with superior physical conditioning (those that can reach 7.2 km/h running stage). In the current study, there were only two individuals who reached this stage.

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None.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data available on request from the authors. https://doi.org/10.25381/cput.22673737.v1.

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