The Relationship Between Level of Physical Activity and Speech Perception Abilities

by

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Introduction

Importance of Speech Perception in Quiet and Noise

The ability to hear and understand speech adequately in quiet and in noise is important for effective communication. The American Academy of Otolaryngology, American Council of Otolaryngology (AAO-ACO, 1979), Hearing Handicap Guide defines normal hearing as, “The ability to identify spoken words or sentences under every-day conditions of normal living.” While the evaluation of speech perception in quiet is necessary, speech-in-noise abilities are of equal importance. Fry (1942) questioned the efficacy of speech-in-quiet and pure-tone threshold testing alone and recommended that hearing also be assessed in conditions that simulated noisy work environments i.e., noisy environments. Fry and colleagues created a speech-in-noise test called the “Efficiency Test” (Dickson et al., 1946). Regarding requirements for their test the authors said, “It must constitute a measure of the candidate's hearing ability when working in ‘real life’ conditions and it must be applied in strictly standardized conditions so that results from different examining centres may be comparable.”

The AAO-ACO (1979) stated “the basis for the calculation of hearing handicap should be altered to reflect a more realistic degree of the understanding of speech, not only in the quiet but also in the presence of some noise.” If auditory function is only evaluated in optimal listening (quiet) environments auditory deficits that only manifest themselves in noisy environments such as daily life will not be fully ascertained. Further, speech-in-noise test results may provide guidance for intervention decisions regarding treatment with hearing aids, cochlear implants, and other assistive listening devices (Taylor, 2003; Beck & Nilsson, 2013)

Psychological Effect of Auditory Dysfunction

Auditory function can be evaluated with pure-tone threshold, speech-in-quiet, and speech-in-noise tests. Functional hearing generally refers to speech perception in quiet and in noise (Vermiglio, 2023). This plays a huge role in a person's everyday life and ability to interact with the world around them. According to Cheng et al. (2019), as children, we rely on auditory input for language acquisition and to begin communicating with others. If this is impeded, it can lead to difficulties later in life. Shukla et al. (2020) performed a review on 14 articles covering the impact of hearing loss (elevated pure-tone thresholds) on older adults. Following a review of multivariable-adjusted studies the authors wrote, "that hearing loss was associated with higher risk of loneliness and social isolation" and this has "important implications for the cognitive and psychosocial health of older adults."

Podury et al. (2023) evaluated the implications of hearing loss on socialization. They reported, "Hearing is essential to the formation of social relationships and is the principal afferent of social life." Note that the negative impact of auditory dysfunction is not limited to those with hearing loss (elevated pure-tone thresholds). King (1954) observed that those with psychogenic deafness (non-organic deafness) suffered from loss of discriminative listening ability especially with background noise and despite normal pure-tone thresholds. It was commonly seen in those who led high-stress careers and particularly those for whom hearing was essential such as airfield runway controller or radiotelephony direction finder operator. King called this condition psychogenic deafness. It has been linked to the development of anxiety and depression (Cleveland Clinic, 2023). This condition has also been called an auditory processing disorder (APD; Pryce et al., 2010).

However, it should be noted that an APD may not always involve speech-in-noise difficulties (Vermiglio, 2019). Furthermore, Saunders and Haggard (1989) reported on obscure auditory dysfunction (OAD), which is self-reported speech-in-noise difficulties in the presence of normal pure-tone thresholds. The authors have linked OAD to anxiety. They found, "Self-reported disability is influenced by anxiety level, but anxiety level and overall history of ontological disorder are also interrelated." This indicates a clear psychological impact on the lives of those with auditory dysfunction even in the presence of normal pure-tone thresholds.

Health Benefits of Physical Activity

Physical activity has been found to successfully reduce these psychological impacts such as anxiety. Martinson (2008) concluded, "The general finding is that state anxiety is significantly reduced following bouts of exercise, both for subjects with normal or elevated levels of anxiety." However, the benefits of physical activities are not restricted to only those of psychological etiology. Warburton et al. (2006) in a review of current literature, reported evidence of the benefit of physical activity on one's health. The authors found that, "There is irrefutable evidence of the effectiveness of regular physical activity in the primary and secondary prevention of several chronic diseases (e.g., cardiovascular disease, diabetes, cancer, hypertension, obesity, depression and osteoporosis) and premature death." Similarly, Janssen and LeBlanc (2010) reported that current literature on younger populations indicated greater levels of physical activity is associated with greater health benefits. The authors concluded that, "To achieve substantive health benefits, the physical activity should be of at least a moderate intensity."

Vogel et al. (2009) found that in older populations, "Moderate but regular physical activity is associated with a reduction in cardiovascular morbidity and mortality, reduction in diabetes incidence and optimization of blood pressure value and lipid profile." Physical activity has also been seen to have a positive impact on hearing abilities. Cristell et al. (2009) conducted a study on 30 subjects with normal hearing (<25 dB HL from 0.25 to 4 kHz) who completed personalized bicycle workouts for eight weeks. The authors found that, "Hearing sensitivity as indicated by pure-tone and TTS [temporary threshold shift] significantly improved in some of the frequencies measured following 8 weeks of exercise training."

Physical Activity and Auditory Function

An observed benefit of physical activity on auditory function has been found in numerous studies. Curhan et al. (2013), surveyed a group of 68,421 female registered nurses aged 25-42 across the United States over the course of 20 years to evaluate the potential impact of physical activity on hearing abilities. Physical activity was measured through a chart and questionnaire participants filled out reporting average time spent per week in the prior year engaging in various physical activities. Their total physical activity was calculated from the reported hours plus the reported number of flights of stairs climbed daily.

Based on collected survey data, the authors reported that women who were more physically active were less likely to develop hearing loss (elevated pure-tone thresholds) than those who are inactive. It was reported that, "Higher levels of physical activity or better cardiorespiratory fitness may protect against hearing loss by improving vascular supply to the cochlea, preventing auditory neurodegeneration and neurotransmitter loss, and possibly moderating noise-induced damage." The authors reported, "Walking was the most common form of physical activity; therefore, we examined the relation between walking and risk of hearing loss. After multivariate adjustment, walking 2 or more hours/week was associated with lower risk of hearing loss (P-trend <.001)."

Similarly, Kawakami et al. (2021) surveyed 27,537 Japanese adults aged 20-80 with normal hearing and evaluated their hearing vs physical activity level. Hearing was evaluated using pure-tone audiometry in a soundproof booth. Following the Japanese Industrial Safety and Health Law, hearing loss was defined as >30 dB [HL] at 1 kHz and/or >40 dB [HL] at 4 kHz. Physical activity level was evaluated using a self-administered questionnaire. The study showed a positive association between level of physical activity and risk reduction in high frequency hearing loss development. The authors reported, “Analysis by sound frequency showed that the amount of physical activity was inversely associated with high frequency hearing loss development (p for trend <0.001).” Further that, “There was a significant inverse association between the amount of leisure-time physical activity (MET-min/week) and incident hearing loss (p for trend = 0.001).” There were no reported r-values.

Physical Activity vs. Speech Perception in Noise

Kearns et al. (2019) studied the impact of physical activity on speech-in-noise perception. The study consisted of 25 college students aged 18-21 with normal hearing. It compared the participants' ability to listen to and repeat stimulus words presented in noise both before and after 30 minutes of aerobic exercise on a stationary bicycle. The study found that, “30 minutes of exercise on a stationary bicycle resulted in an increase in the ability of participants to identify words embedded in noise. This indicates that aerobic exercise can enhance auditory perception.” The authors’ stated, “A paired samples t-test revealed that there was a significant difference in the number of words correctly identified during session one (M= 25.4) and session two (M=29.83), t(24)= -3.97, p=.001. Participants identified significantly more words after aerobic exercise.” Kearns et al. (2019) also urged for further investigation on the topic explaining, “Future work should examine the effects of long-term exercise and fitness levels on aging and hearing.”

Working Memory vs. Speech Perception in Noise

Parbery-Clark et al. (2009) evaluated the connection between working memory and speech perception in noise abilities. The study compared working memory and speech perception in noise performance between two groups of 16 musicians and 15 nonmusicians. It included participants completing complex tasks requiring high levels of working memory as well as the Quick Speech-in-Noise test (QuickSIN; Killion et al., 2004) and Hearing in Noise Test (HINT; Nilsson et al., 1994; Vermiglio, 2008). Fine-grained frequency discrimination (the ability to discriminate between frequencies) was also evaluated through this testing. The results revealed that, “Musicians outperformed the nonmusicians on both QuickSIN and HINT, in addition to having more fine-grained frequency discrimination and better working memory.” The reported values for the QuickSIN and HINT in relation to working memory were ($r = 0.369$, $p < 0.01$) and ($r = 0.369$, $p < 0.05$) respectively.

Hypothesis:

Hypothesis 1: What is the relationship between level of physical activity vs. pure-tone threshold? Based on Kawakami et al (2021) and Curhan et al (2013) it was hypothesized that there would be a statistically significant relationship between these two variables.

Hypothesis 2: What is the relationship between level of physical activity vs. performance on speech-in-noise tests? Based on Kearns et al (2019) it was hypothesized that there will be a statistically significant relationship between these two variables.

Hypothesis 3: What is the relationship between level of physical activity vs. performance on auditory working memory test? According to Kearns et al (2019) there is a relationship between performance on speech-in-noise tests and physical activity and according to Parbery-Clark (2009) there is a statistically significant relationship between speech-in-noise performance and working memory. Therefore, it is hypothesized that there will be a statistically significant relationship between auditory working memory and physical activity.

Methodology:

Permission to conduct this study was granted by the University Medical Center Institutional Review Board (UMCIRB) and the East Carolina University College of Allied Health Sciences. Twenty-three native English speakers with normal pure-tone thresholds (≤ 25 dB HL, 0.25 - 8.0 kHz) were included in this study. All behavioral testing was conducted with either unilateral or bilateral stimulus presentations under supra-aural headphones in a sound-treated booth. All participants underwent pure-tone audiometry using the Hughson-Westlake protocol. All speech perception measures were randomized. Bilateral pure-tone averages (BPTA) were calculated for thresholds at 0.5, 1.0, 2.0, 3.0, 4.0, and 6.0 kHz. The standard Hearing in Noise Test (HINT; Nilsson et al., 1994; Vermiglio, 2008) protocol was administered for the Noise Front condition. The HINT threshold is the signal-to-noise ratio (SNR) where the participant recognizes 50% of the sentences. The HINT sentences were presented in steady-state speech-shaped noise 65 dBA.

The AzBio (Spahr et al., 2012) sentences and ten-talker babble were presented at 65 dBA (0 dB SNR). Ten out of the original fifteen AzBio Sentence lists were used in this study. These ten sentence lists were reported by Schafer et al., (2012) to have equivalency in difficulty. The Digit-Span test (Wechsler et al., 1991) was administered to all participants. The participants' task was to listen to and repeat strings of digits in reverse order (backwards). This is a measure of auditory working memory ability. Figure 1 shows the following question which participants were asked in relation to their physical activity, "How would you describe the average level (exertion) of your overall physical activity in the past 6 months?" With the answer options being on a 6-point Likert scale of: 1. I did not engage in physical activity, 2. Low exertion, 3. Some exertion, 4. Moderate exertion, 5. High exertion, and 6. Maximum exertion. The relationships between self-reported level of physical activity vs. behavioral test results were evaluated with the Spearman rho statistic using the JMP Pro 16 statistical software.

Results:

The descriptive statistics for all test conditions are presented in Table 1. Despite the participants all having normal pure-tone thresholds ($\leq$ 25 dB HL, 0.25 - 8.0 kHz), a wide range of performances were seen in the behavioral testing. The mean for the binaural pure-tone average (BPTA) was 4.22 dB HL. This represents the lowest level on average that the participants could hear. The mean for AzBio score was 49.61%. This means that, on average, participants correctly repeated 49.61% of the words presented in 10-talker babble at 65 dBA. The range was 73.34 percentage points. The mean for the HINT threshold was –0.51 dB SNR. This means that, on average, participants correctly recognized 50% of the sentences when the speech was 0.51 dB below the 65 dBA noise. The range was 3.5 dB.

The mean for the Digit Span scores was 6. This means that, on average, participants correctly repeated number strings of 6 digits in length. Figure 2 is a scatterplot of level of physical activity vs. BPTA. There was a wide range of BPTAs (17.5 dB). A weak negative correlation was found for level of physical activity vs. BPTA ($r = -0.21$, $p = 0.33$). Figure 3 is a scatterplot of level of physical activity vs. HINT thresholds. It shows a weak negative correlation (r = -0.36, *p* = 0.10). Figure 4 is a scatterplot of level of physical activity vs. AzBio scores. It shows a very weak positive correlation (r = 0.15, *p* = 0.50). Figure 5 is a scatterplot of level of physical activity vs. Digit Span Backward Scores. It shows a very weak positive correlation (r = 0.18, *p* = 0.42).

Discussion:

Contrary to the three hypotheses, no statistically significant relationships between variables were found. Beginning with Hypothesis 1, there was a weak negative relationship (r = -0.22, *p* = 0.33) between the subjects' level of physical activity in the past 6 months vs. their binaural PTA. This is inconsistent with the findings of Kawakami et al. (2021) and Curhan et al. (2013) who reported a statistically significant relationship between physical activity and overall hearing abilities. Regarding Hypothesis 2, the AzBio and HINT were used to assess speech in noise abilities in comparison to the subjects' level of physical activity in the past 6 months. The HINT thresholds in relation to physical activity, showed a weak negative relationship (r = -0.36, *p* = 0.10), while the AzBio scores in relation to physical activity, showed a very weak positive relationship (r = 0.15, *p* = 0.50). This is inconsistent with the findings of Kearns et al. (2019) who reported a statistically significant relationship between physical activity and speech-in-noise abilities.

Finally, with Hypothesis 3, there was a very weak positive relationship (r = 0.18, *p* = 0.42) between the subjects' level of physical activity in the past 6 months vs. their performance on auditory working memory tests. This is inconsistent with the findings of both Kearns et al. (2019), who reported a statistically significant relationship between physical activity and speech-in-noise abilities, and Parbery-Clark (2009) who reported a statistically significant relationship between speech-in-noise abilities and working memory. Possible reasons why study data was in contrast with current literature may include having a smaller number of participants (n =23) and the wide variation in test performance despite all participants having normal pure tone thresholds ($\leq$ 25 dB HL, 0.25 - 8.0 kHz).

Future Research:

Overall, there were no statistically significant relationships found supporting the hypotheses that there would be a relationship between level of physical activity and the three assessed variables of pure-tone threshold, speech in noise perception abilities, and working auditory memory. These results were found to be inconsistent with the aforementioned studies evaluated in the literature review including Kawakami et al. (2021) and Curhan et al. (2013), Kearns et al. (2019), and Parbery-Clark (2009). Further research on this topic is encouraged to better understand the evaluated relationships. It is suggested to include larger subject pools and take into consideration test performance variation in conjunction with pure-tone thresholds. Insight on these relationships is a worthwhile pursuit as it may lead to better understanding on whether physical activity is a mitigating factor for audiologic dysfunction.

Clinical Implications:

The wide range of test results from participants with normal pure-tone thresholds indicate that pure-tone thresholds are insensitive to some auditory disabilities. Regarding the AzBio test, the minimum score was 4.35% (representing a poor performance) and the maximum was 77.69% (representing a good performance). The range of 73.34 percentage points represents a significant difference in speech perception in a noisy environment. This information may be valuable for counseling purposes. It is shown that a speech-in-noise test may reveal listening difficulties not observed through pure-tone audiometry which is the most used measure of auditory function. There are no clinical implications to report regarding the relationship between level of physical activity to pure-tone thresholds, speech-in-noise ability, and working memory as no statistically significant relationships were found.

Test Name	Mean	Standard Deviation	Minimum	Maximum	Range
BPTA	4.22 dB HL	4.01	-1.67 dB HL	15.84 dB HL	17.5 dB
AzBio	49.61%	23.97	4.35%	77.69%	73.34 percentage points
HINT	-0.51 dB SNR	0.95	-2.1 dB SNR	1.4 dB SNR	3.5 dB
Digit Span	6	2.05	3	12	9

Table 1. Descriptive statistics for all variables (n=23)

How would you describe the **average level** (exertion) of your **overall** physical activity in the past **6 months**?
1. I did not engage in physical activity
2. Low exertion
3. Some exertion
4. Moderate exertion
5. High exertion
6. Maximum exertion

Figure 1. Question on subject's self-reported physical activity in past 6 months.

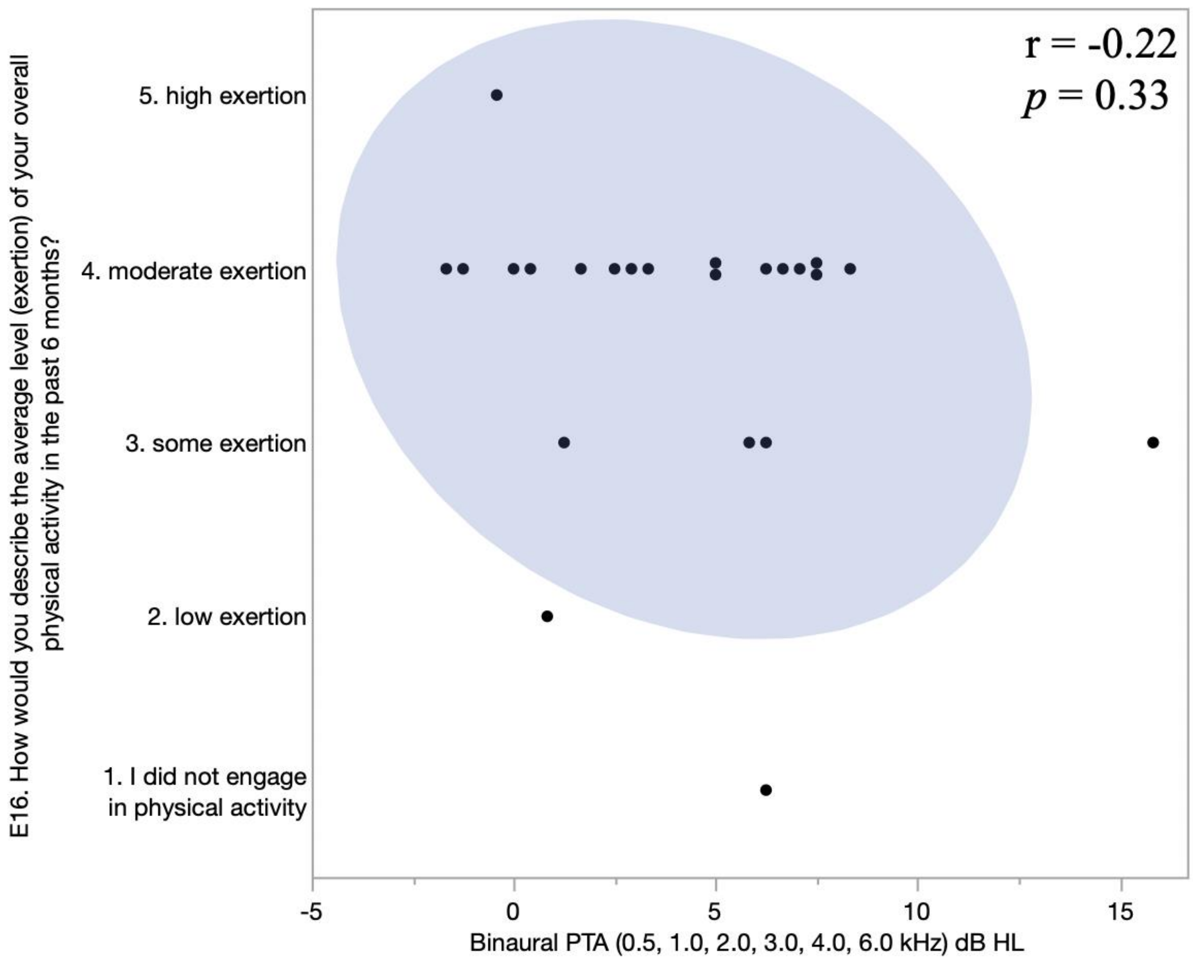

Figure 2. Level of Physical Activity vs. BPTA.

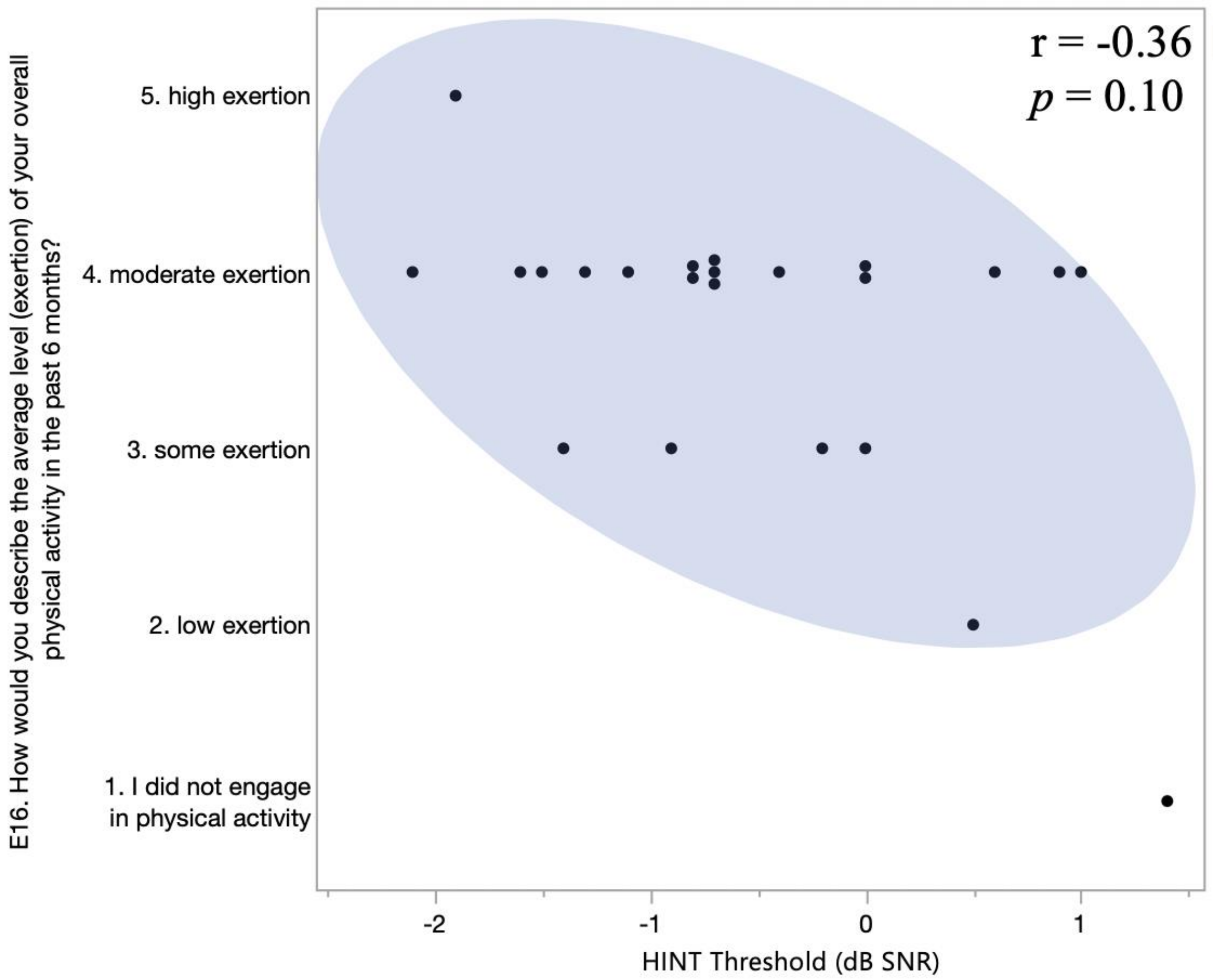

Figure 3. Level of Physical Activity vs. HINT Threshold.

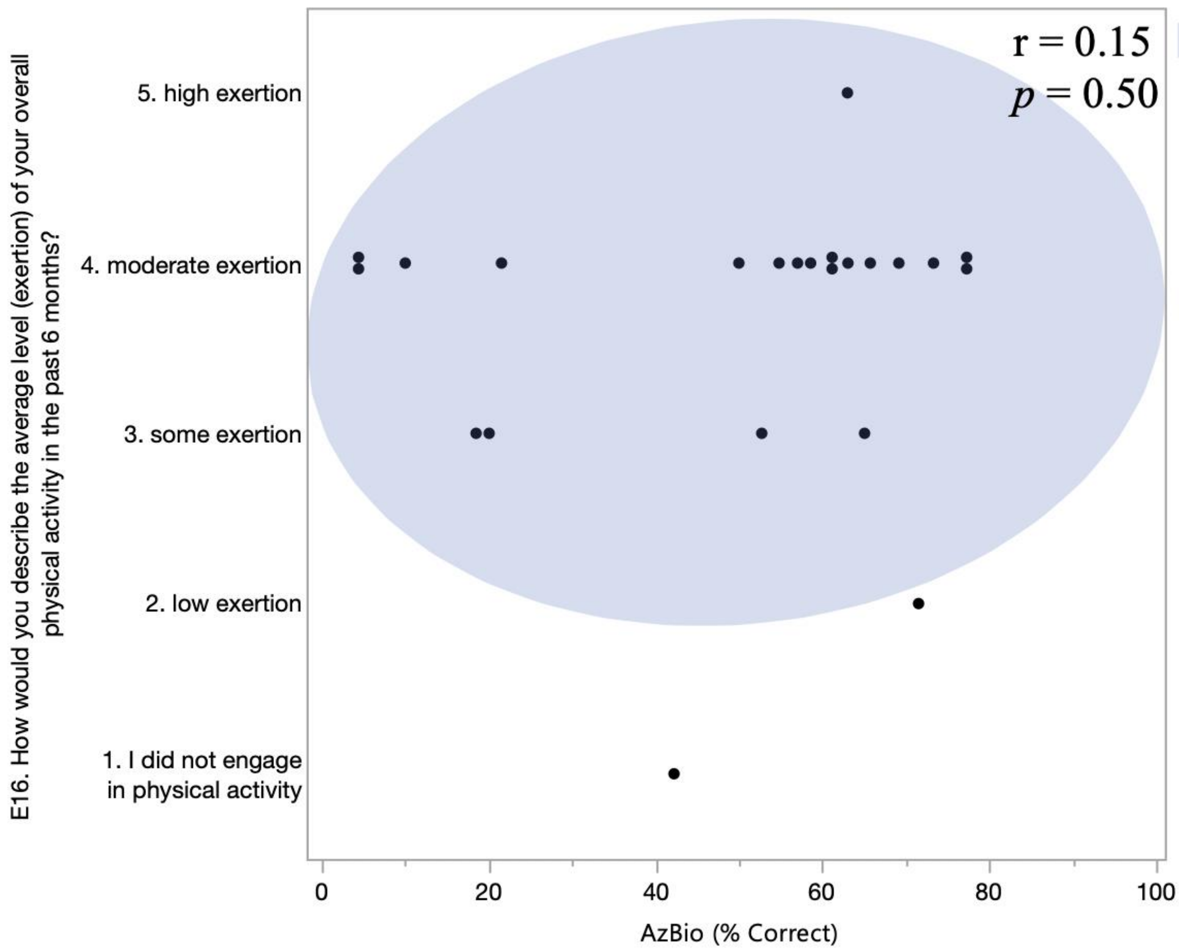

Figure 4. Level of Physical Activity vs. AzBio Score.

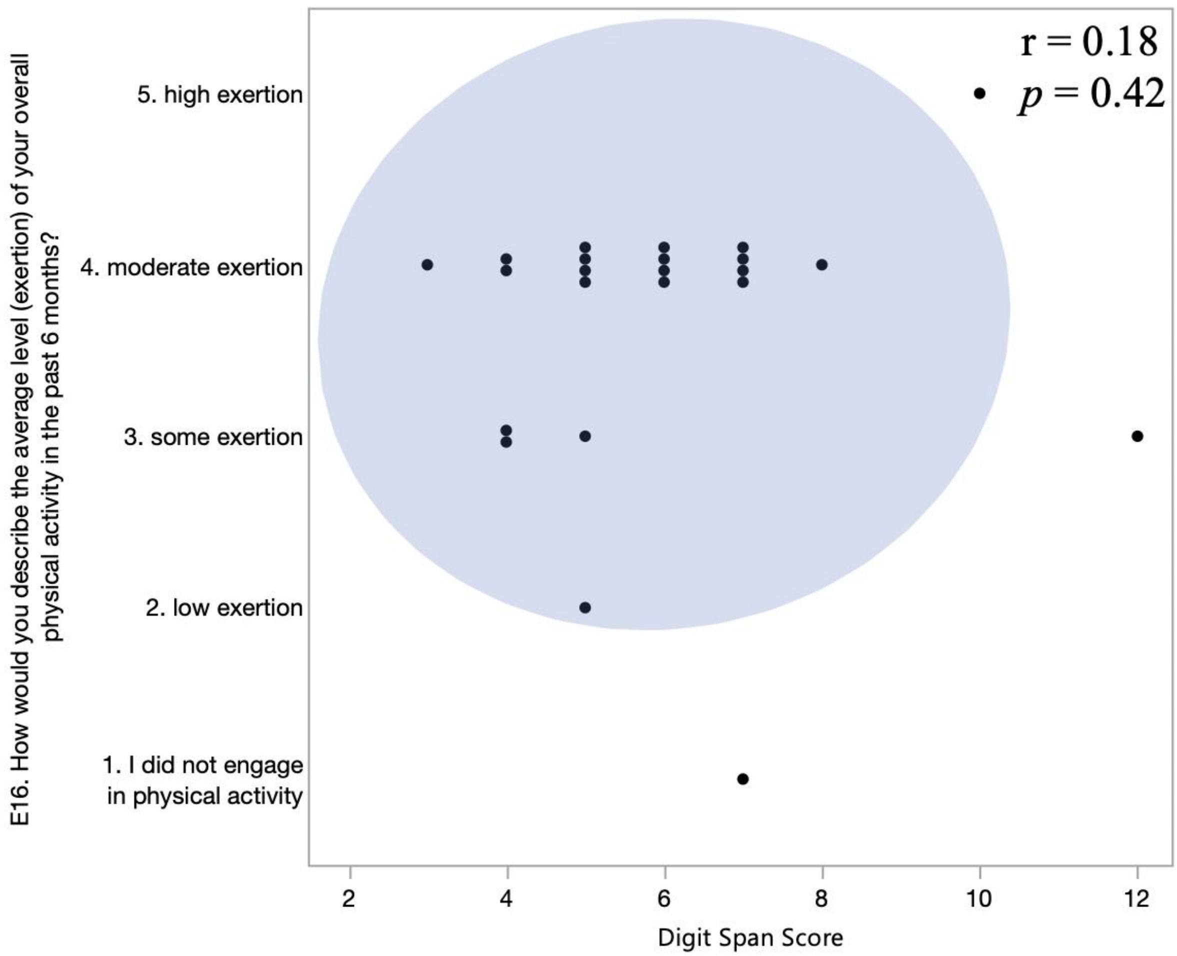

Figure 5. Level of Physical Activity vs. Digit Span Score.

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