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The relation between physical exercise and impulsivity during adolescence

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Contents

Abstract

During adolescence people undergo a vast array of neurological changes. Adolescents show increased levels of impulsivity due to an imbalance in neurological maturation. A plethora of literature looks into this subject and how this development can be influenced via healthy behaviours like physical exercise. This longitudinal study hypothesized that physical exercise has a decreasing effect on the development of impulsivity. Multiple regressions were carried out cross-sectional as well as longitudinal to assess whether physical exercise had a significant positive effect on impulsivity within one time point and over time. Cross-sectional results showed that a higher cardiovascular condition is strongly related to lowered impulsivity. The longitudinal analysis showed no significant results, implying that the effect of exercise on inhibition is not significant over time. This study provides preliminary evidence that exercise may have beneficial effects on adolescents' levels of impulsivity, and discusses practical implications

Keywords: Impulsivity, exercise, Sports, Adolescence, Cross-sectional, Longitudinal.

Introduction

Adolescence, the developmental time period between childhood and adulthood (Brenhouse, & Andersen, 2011; van den Bos, & Hertwig, 2017; Juraska, & Willing, 2017) is a turbulent period in every person's life, as it is accompanied by a cascade of developmental, biological, psychological and personal consequences. Adolescents tend to be susceptible for impulsive behaviour, in their social life, sexual behaviour, and experimentation with substances (e.g. alcohol or drugs) (Steinberg, 2007; Steinberg, 2011; Shulman, Smith, Silva, Icenogle, Duell, Chein, & Steinberg, 2016; van den Bos, & Hertwig, 2017). Over time, the scope of developmental psychology shifted from the individual child to that of a more holistic approach to attain a more intricate understanding of development during adolescence (D'Amato, Zafiris, McConnell, & Dean, 2011). As a result of this development, the role and beneficial effects of physical exercise became important research topics. In this case research on physical exercise is important, considering that it has a broad array of beneficial effects on developing individuals, ranging from an increase in overall well-being (Jewett, Sabiston, Brunet, O'Loughlin, Scarapicchia,& O'Loughlin, 2014), positive effects on perceived stress and emotional development (Vella , Cliff, Magee, & Okeley, 2015), stronger executive functions development (e. increase in inhibitory control) (Ludyga, Gerber, Brand, Holsboer-Trachsler,& Pühse, 2016), and benefits in self-regulation (Audiffren, & Andre, 2015; Gearin, & Fien, 2016). The current study examined the effect of exercise on impulsivity across adolescence. We hope to find out whether the development of impulsivity could be influenced, enabling adolescents to increase control over their actions.

Impulsivity

Impulsive behaviour can be broadly defined as actions that are not fully thought through, unnecessary risky, situational inappropriate and often leading to undesirable outcomes (Evenden, 1999). Impulsivity is also a marker of adolescent behaviour. Literature is consistent in how this develops, as studies suggest that impulsivity has a linear decrease from childhood to adulthood (Juraska, & Willing, 2017). However, this linear decline is accompanied with a peak of risk-seeking behaviour during the adolescence (Steinberg, 2007; Steinberg, 2010; van den Bos, & Hertwig 2017). Steinberg (2007) explained this peak of risk-seeking behaviour as an effect of the so-called *temporal gap*. The brain develops from the back to the front, so the limbic system (i.e. the ‘hot’ socio-emotional network) that lies in the middle of the brain, matures much earlier than the prefrontal cortex (i.e. the ‘cold’ cognitive control network) which is found in the front of the brain. As a consequence, an adolescent is at emotional and social level already functioning like an adult, while brain areas for cognitive control and inhibition are not yet fully mature (Steinberg, 2007; Steinberg, 2010) . Due to this incongruence, adolescents are more susceptible for exciting, pleasurable and overall more risky behaviours. However, as maturation of the brain continues, a developing adolescent shall experience an increase in control over these impulses because of prefrontal development (Steinberg, 2007; Shulman, et al., 2015; Juraska, & Willing, 2017).

Although adolescence is often described as a period of heightened impulsivity not all adolescents show rash behaviour. There is a rather important factor that may attenuate impulsive actions, self-control. Self-control ensures the allocation of effort to meet demands of a certain task. According to Baumeister’s theory it is a limited resource that can be allocated and depleted when people engage in tasks that require self-regulation (Audiffren, & André, 2015; Muraven, & Baumeister, 2000; Baumeister, & Tierney, 2011). After depletion, the resource needs time to replenish. However, research showed it is not a resource with a fixed quantity. Self-control can actually be trained like a muscle and thereby its volume increases (Audiffren, & André, 2015; Muraven, & Baumeister, 2000). Therefore, when self-control can be enhanced through regular depletion it may also decrease impulsivity over time. This could further entail that training of self-control has a positive effect on the development of impulsivity in adolescence. A factor that positively enhances self-control is physical exercise (Audiffren, & André, 2015).

A large body of research has shown that physical exercise has a wide range of effects, short term and long term, on mental as well as physical health (Teixeira, et al., 2012). The short term effects are described as 'acute' effects, implicating that even after one single bout of exercise, there are already notable differences in cognitive performance (Ludyga, et al., 2016). Although acute effects have been found in literature, the most positive and beneficial effects have been observed in chronic exercisers. They were observed to have higher levels of self-control and consecutively lower levels of impulsivity (Audiffren, & André, 2015; Ludyga, et al., 2016). The matter of how physical exercise interacts with impulsivity in adolescence has not been researched extensively yet.

The effect from exercise on mental health

Physical exercise is healthy and shows physical and psychological benefits for people in all age groups (Ludyga, et al., 2016; Vella, et al., 2015; Diamond, 2012; Voelcker-Rehage, & Niemann, 2013; Erickson, Leckie, & Weinstein, 2014). Physical effects result in the facilitation of cortical activity (Abel, & Rissman, 2013), blood circulation and metabolism (Ludyga, et al., 2016; Cotman, Berchtold, & Christie, 2007; Hötting, & Röder, 2013). Psychological effects range from lowered depressive symptoms, lower perceived stress and higher self-rater mental health, as well as an increase of feeling of social belonging, mastery and interconnectedness with peers (Jewett, et al.,, 2014), an increase of discipline (Vella, et al., 2015), improved self-control (Audiffren, & André, 2015) and better executive functioning (Ludyga, et al., 2016; Diamond, 2012; Crova, Struzzolino, Marchetti, et al, 2014). Aside from these benefits, it is also already available, easy to implement, non-invasive, and more cost-effective than remedial programs. When a positive effect from exercise on the development of impulsivity is observed, a compelling argument could be made to promote more physical exercise in schools, as well as invest more attention to school exercise as a whole.

Impulsivity and Exercise

When regarding physical exercise and its beneficial effects an interesting question can be identified: does physical exercise influence these levels of impulsivity? As physical exercise programs show positive effects on children's behaviour, general state of well-being, and most importantly a positive effect on self-control, it is a matter worth looking into (Jewett et al., 2014; Vella, et al., 2015).

Jewett and colleagues (2014) showed that participation in a school sport program decreased depressive symptoms and increased general well-being in primary school children. Another study by Vella and colleagues (2015) showed that children who participated in sport activities had less psychological difficulties over a 2 period time in comparison to those who dropped out. A meta-analysis by Ludyga and colleagues (2016) looked into the relation between executive function and exercise, they found that individuals who are going through developmental changes have the highest benefit from aerobic exercise (i.e. show a higher higher sensitivity in executive functions). Still, this study mostly looked at cross-sectional studies regarding the comparison of adolescents to elderly people, so no direct inferences could be made about the influence of impulsivity in adolescence. However, these studies do highlight that sport has: positive influences on mental health development (Vella, et al, 2015; Jewett, et al, 2014), on later exercise behaviours (Janz, Dawson, & Mahoney, 1999) and, more specifically, on the development of impulsivity (Ludyga, et al., 2016). It is important to invest more in longitudinal studies of physical exercise on the development of properties like inhibition. Therefore we wished to replicate findings about the effect of exercise on impulsivity across adolescence and thereby strengthen the base of knowledge around this topic.

Current study

The current study used a longitudinal design with two time points to predict impulsivity development from exercise on the concurrent time point, and two years prior, in a large sample of adolescents. We hypothesized that adolescents who more actively participate in exercise show lower levels of impulsivity over time, in contrast adolescents exercise less often. In this research we involved the intensity of the exercise (i.e. weekly amount of hours invested in exercise), the total amount of years spent exercising so far, the level of cardiovascular condition and the setting in which the exercise took place (i.e. an individual- or team sport). The setting variable was included with the aim to find out if there is a difference between the individual exertion and a persons' exertion in team performance. Ultimately it is hypothesized that those who invest more hours weekly in exercise, exercise the longest, and have the highest scores on cardiovascular condition show the lowest levels of impulsivity. Furthermore, we expected these relation are observed above the effect of age on impulsivity as impulsivity is proven to decrease with age (Steinberg, 2007; Steinberg, 2010). If this study indeed proves that exercise explains lower levels of impulsivity, it could provide people with an active method to possibly counteract impulsivity and its potential dangerous outcomes. When more would be known about the influence of physical exercise, it could provide governments a compelling reason to increase the amount of physical exercise during education.

Method

Participants

The participants were recruited for the Braintime study, a longitudinal study that included 300 participants between the age range of 9 and 25years at time point 1 (see also Schreuders et al., 2018; Peters, & Crone, 2018). Recruitment was carried out via schools and advertisements. Sample size varied over time. At the first time point (T1) there were 299 participants, at T2 it was a group of 287 participants and at T3 275 participants took part in the study. Only the participants who participated at both T2 and T3 were included in this study, because since the second time point exercise was included in the study. This research was not aimed at the development outside of adolescence so participants outside of the age range 12-18 years were excluded. This left us with a number of 197 participants at T2 (M_{age}= 15.3; SD_{age}=1.87) and 186 participants at T3 (M_{age}=17.30; SD_{age}= 1.90). As the study aimed to cover a broad population, eight participants who had psychological disorders were included therefore included as well.

Questionnaires

In order to study impulsivity levels the Baratt Impulsiveness Scale (BIS-11) was used (Stanford, Barratt, & Patton, 1995). This questionnaire consisted of 30 items with three subscales: 1) attentional impulsiveness; 2) motor impulsiveness; 3) non-planning impulsiveness. As all constructs contributed to impulsivity and this research is not aimed at a sub construct of impulsivity it was decided to use the total scale as the response variable.

The questionnaire used to study sport-behaviour/physical condition consisted of 13 items. From the exercise questionnaire the items about the amount of hours invested in exercise were considered most meaningful. Another item inquired about the total time (in years) someone has invested in exercise. This is important because this tells us if someone is a chronic exerciser or has started recently. Another variable here described the distinction whether the sport at hand was either practiced in a team setting (e.g. football or hockey) or an individual one (e.g. tennis, archery, or a martial art). This variable was included because it could tell us whether there are any differences between those who exercise in a team or individually. The reason this variable was added was to see there would be a difference in exertion and consecutively also in a difference in impulsivity. In order to make it measureable in SPSS we converted it to a four point scale, (i.e. 0= no sport; 1= team sport; 2= individual sport; 3= both team and individual). Lastly there are three items that were viewed as the variable of cardiovascular condition. These items assessed at what degree of exertion someone starts to feel tired (e.g. jogging, 5-120 minutes or walking 10 – 60 steps in a staircase). This last variable served as a check to see if the amount of physical activity not only is visible in the hours spent, but also in a change of physical condition. Items measuring cardiovascular condition showed development of physical condition, these were included to also shed light on actual physical performance of the participants and clarify how a good physical condition was related to impulsivity levels. The three variables intercorrelated significantly (see figure 1), therefore the raw scores were added up and the sum score was used as the cardiovascular variable.

Table 1.
Correlation matrix of the items measuring cardiovascular condition

	1.	2.	3.
1. Jogging 5-120 minutes	-		
2. Climbing steps 10-60	,428*	-	
3. Running 1km- <10km	,431*	,568*	-

Note. *Correlation is significant at p<.001 (2-tailed)

Summing up, the 13-item questionnaire was brought back to 4 variables: 1, weekly amount of physical exercise in hours; 2, total amount of years exercising; 3, setting (individual - or team sport); 4, cardiovascular condition.

Data Analyses

We hypothesized that people who participate more in exercise show lower levels of impulsivity. In order to test this hypothesis a multiple regression was used. The multiple regression analysis has a stepwise design. First, age was entered as a predictor variable in order to verify if age on its own was not already sufficiently predictive. Second, the sports variables were entered into the analysis.

The regression analysis was carried out twice. The first run checked whether the value of the exercise variables at the second time point (T2) was significantly correlated with the impulsivity outcomes at the same time point. When significant results were found the regression analysis was to be carried out with the sports variables from T2 and the BIS-11 outcomes of T2 as predictor variables and the BIS-11 outcomes of T3 as the response variable. Doing so we could assess whether the exercise behaviours of our participants were significantly predictive of their impulsivity levels over 2 years time.

Results

In this study we wanted to find out whether the level and intensity of physical exercise during adolescence has a significant effect on the development of impulsivity. We used a sample of participants who were administered the BIS-11 and a sport questionnaire at two different time points.

Initially, only T2 was examined in order to see whether the expected effect would be found at this time point. After exclusion of participants outside the age range 12-18, the sample consisted of 197 participants (98 were female, 99 were male; M_{age}= 15.32; SD_{age}= 1.87).

Descriptives of the BIS-11 showed that these results fell in a range of 59, between 41 and 100 (M= 63.14; SD= 9.37). Hours exercised showed a range between 0 and 6 (M= 2.34; SD=1.5), meaning all participants at least invested one hour in sports. Total amount of years invested in exercise varied over a range of 6 years, with the minimum at 0 (M= 4.03; SD= 1.76). Cardiovascular condition ranged from 4 to 18 (M=12.40; SD= 3.27). With regards to the setting variable it was found that only 32 did not participate in a sport whatsoever, 59 participants participated in a team sport, 74 participants participated in an individual sport and 31 participated in both a team and an individual sport.

Cross-sectional analysis

Initially, the correlations between the predictor variables and the outcome variable were consulted. As Table 1 portrays, age is significant negatively correlated to impulsivity. Furthermore, impulsivity, impulsivity showed significant negative correlations with the amount of weekly hours spent exercising and cardiovascular condition. Finally, impulsivity showed no significant correlation to sport setting or the amount years put into exercise. The variables did have intercorrelations of which some were significant (see Table 2**.**).

Table 2.
Correlation matrix of the BIS-11 and the exercise variables

	1.	2.	3.	4.	5.	6.
4. BIS-11	-					
5. Age	-.120*	-				
6. Weekly hours exercised	-.129*	-.073	-			
7. Total amount of sport participation (in years)	.028	.199**	.345***	-		
8. Setting (Team/Individual)	-.040	-.210**	.549***	.366***	-	
9. Cardiovascular Condition	-.264***	.153*	.308***	.295***	.173**	-

Note. ***Correlation is significant at p<.001, **Correlation is significant at p<.01, *Correlation is significant at p<.05

Next, we ran a multiple regression analysis in which we predicted impulsivity at T2 from the sports variables at T2 (i.e., weekly amount of hours exercised, years of sport, setting, and cardiovascular condition). All assumptions necessary for the conduction of multiple regressions have been met (see Appendix A). The variables were entered stepwise, first only age was put into the analysis to see if age had any significant effects on its own. In the second step, the sport variables were added. Age on its own explained 1.4% of the variance ($F(1,194)=2.812$; p =.095). Addition of the sports variables increased the explained variance to 10.3% (ΔR^2 =.089; $F(4,190)$= 4.701; p=.001).

In order to find out if the variance of our predictor variables was significant, the Anova results were consulted. With only age entered into the analysis the result was not significantly predictive ($F(1,194) = 2.812$; $p = .095$). After addition of the sports variables the anova table yielded significant results ($F(5,190) = 4.367$; $p = .001$). This outcome tells us the combination of the four predictor variables leads up to a significant explanation of the BIS-11 measures.

Table 3.
Regression coefficients from cross-sectional analysis at T2

	b	*SE b*	*β*
Step 1			
Age T2	-.601	.358	-.120
Step 2			
Age T2	-.647	.374	-.129
Weekly hours exercised	-.635	.532	-.103
Total amount of sport participation (in years)	.940	.426	.176*
Setting (Team/Individual)	-.299	.868	-.030
Cardiovascular Condition	-.742	.214	-.259**

Note: $R^2 = .014$ for Step 1, $\Delta R^2 = .089$ for Step 2 ($p < .001$). *$p < .05$, **$p < .001$.

Inspection of regression coefficients indicated that this significant model was driven by the total amount of years our participants invested in exercise as well as by their cardiovascular condition. However, though the amount of years exercised turned out to predict impulsivity positively. Thus, the better someone's cardiovascular condition is (i.e. being able to climb more steps, walk longer distances, run for a certain amount of time) the lower that persons impulsivity is (see Table 3).

To further clarify the effects from years invested in exercise and cardiovascular condition on impulsivity, we visualized the data in a scatter plot. As can be seen in Figure 1 there is a clear negative relation between cardiovascular condition and impulsivity.

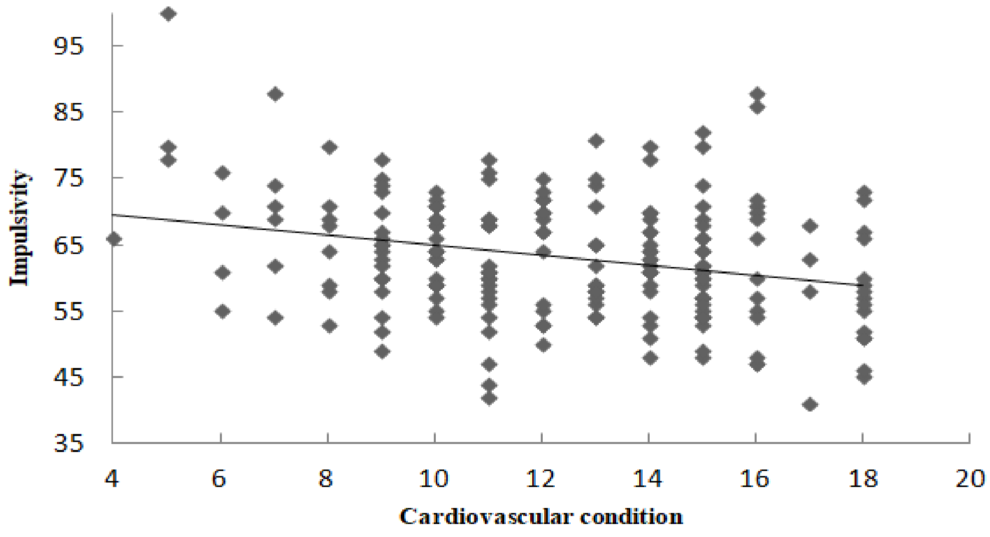

Figure 1. *Correlation between impulsivity and cardiovascular condition*

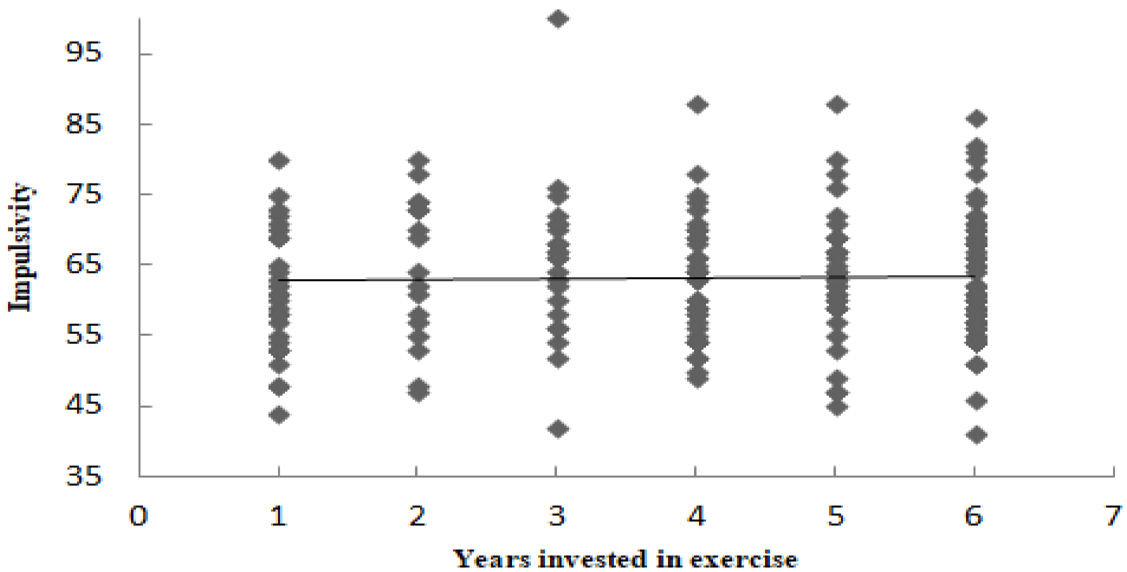

Figure 2. *Correlation between impulsivity and years exercised*

However, as the results indicated the relation between years invested in exercise and impulsivity was positive (r=.028, p=.350). This positive relation was appeared less pronounced than the relation between cardiovascular condition and impulsivity (see Figure 2).

Longitudinal Analyses

After finding an overall significant result for the cross-sectional analysis in T3 we explored whether sport at T2 was predictive of impulsivity two years later at T3. All assumptions necessary for the conduction of multiple regressions were met (see appendix B).

This analysis was carried out with a stepwise design. First, age and the impulsivity data of the previous time point were entered to control for age and time related changes. Second, the sports variables of the previous measurement were entered into the equation.

To ascertain to what extent the variables explained the outcomes on the BIS-11, the Anova table was consulted. The model with age and the impulsivity outcomes was significant ($F(2{,}168) = 54.541$; $p<.001$). Together with a significant F-change ($p<.001$). The second model with the exercise variables was also significant ($F(4{,}166) = 27.407$; $p<.001$). However, the F-change was not significant ($F(2{,}166)=,559$; $p=.573$), which shows the explained variance of the second model is driven by the age effects and the developmental effects. Inspection of regression coefficients confirmed this notion (See Table 3).

Table 3.
Regression coefficients of the longitudinal analysis

	B	*SE B*	*β*
Step 1			
Age T2	-.574	.288	-.121*
BIS-11$_{T2}$	.569	.057	.602**
Step 2			
Age T2	-.608	.295	-.128*
BIS-11$_{T2}$	.587	.060	.620**
Total amount of sport participation (in years)	-.050	.337	-.010
Cardiovascular Condition	.188	.178	.070

Note. R^2=.627 for Step 1, ΔR^2=.004 (p=.573). *p<.05, **p<.001.

Discussion

This study examined the effect of physical exercise on the development of impulsivity through adolescence. Here, we were particularly interested if exercise would be predictive on the outcomes of impulsivity over a period of two years. The results of this study ambiguously confirm our hypothesis. The positive influence of physical exercise on impulsivity has been proven, but only partially, which shall be explained in this discussion.

Main results were that there was a significant negative relation between exercise and impulsivity, as was also found in the literature (Ludyga, et al., 2016; Crova, et al., 2013). However the results of the analyses differed between the cross-sectional analysis and the longitudinal analysis. In this discussion the results shall first be discussed where after we shall mention some limitations and future research directions for this subject. Finally a conclusion shall be provided.

Cross-sectional results showed that there was a significant effect from exercise on impulsivity when it came to the total amount of years a participant invested in exercise and their cardiovascular condition (Ludyga, et al., 2016; Audiffren, & André, 2015). However, the amount of years invested in exercise had a positive relation with the outcome of impulsivity, and cardiovascular had a negative relation. In other words, someone with high scores on condition high levels of impulsivity. As does someone who committed him- or herself for many years into a sport have higher levels of impulsivity. This finding is partly inconsistent with literature, as the chronic exercisers were the group that would have lower impulsivity (Ludyga, et al., 2016).

Longitudinal analysis showed no significant relations between the variables that turned out significant in the cross-sectional analyses. Here, we included the variables of cardiovascular condition and years invested in exercise because of significant results in the cross-sectional analysis. Impulsivity was here significantly predicted by the model we created.

However it turned out the significance was all due to the effect of the age and previously acquired impulsivity scores, which is consistent with literature (Steinberg, 2007; Steinberg, 2010; Brenhouse, & Andersen, 2011; Spear, 2013; Shulman, et al., 2016). In our analysis the exercise variables were not significant and therefore were not predictive for impulsivity levels two years from then. Thus, no significant effect was found of our exercise variables on impulsivity over two years. This outcome shall be discussed more elaborately later.

Limitations of this study include the fact that exercise was assessed with a questionnaire. Physical exercise is a construct that can be described, but there were no safeguards implemented to ensure the participants provided a truthful image about their physical state. To specify, cardiovascular condition was assessed by asking the participants how much exertion they could have before failure. This might better be assessed with a condition test (e.g. shuttle-run test or another supervised general fitness test). To add to this, the BIS-11 does not measure impulsivity directly, but self-reported impulsivity. With self-report there is always the error of social desirable outcomes. When an observational assessment would have been used there would probably be a more valid approach towards this subject. Because of the self-reported nature of this research it is unclear whether the outcomes of the longitudinal study are truly insignificant or a result of error. Therefore, replication of this study, with the use observational assessments, is strongly encouraged.

In a future research it could also be interesting to approach the subject of exercise more broadly. For instance there might be a discrepancy between groups of people who exercise out of an intrinsic or extrinsic motivation (Teixeira, et al., 2012). Especially because some animal studies focus on voluntary exercise behaviour and observed large differences with samples with a sedentary condition included (Abel, & Rissman, 2013). Furthermore, it would be interesting if there these results would translate to a sample of highly impulsive people (e.g. ADHD, behaviour disorders, personality disorders). For instance, a study as the current one could be repeated in a clinical setting to examine if effects of cardiovascular condition have a different effect on people with disorders that are typically highly associated with higher levels of impulsivity. Literature suggested that those with a lower baseline of cognitive function experience a higher benefit from an exercise intervention (Crova, et al., 2013) and that regular exercise has a beneficial effect on the expression from many disorders (e.g. autism, schizophrenia, ADHD) (Abel, & Rissman, 2013).

In our study we included the setting variable to assess whether there would be a difference in outcomes between those who participated in an individual sport or a team sport. We reasoned it could work in two ways. On the one hand, the individual exercisers could have worked harder because they had to do the work for themselves and themselves only, while the team sport participants could only do their smaller part in the overall performance. Otherwise, the team sport participants exercised harder because they felt the social incentive to pay their maximum effort and the individual exercisers would fall behind. As insignificant results were found this line of reasoning was not further pursued, but it may be worthwhile to further investigate this idea. For instance, exercise addiction was found the be generally higher in people who practiced fitness compared to football players, while football players were most interested in enjoyment and competition, the fitness group was most focused on increase in health and strength (Lichtenstein, Larsen, Christiansen, Støving,& Bredahl, 2014). Perhaps, this difference in incentive could have influences on the manifestation of impulsivity. There could be a relation between the prevalence of exercise addiction, the development of cardiovascular condition and thereafter the manifestation of impulsivity. To ensure this relation exists, further study would be necessary. It would still be interesting, since addiction is seen more in adolescence, due to immature emotional regulation strategies (Froushani, & Akrami, 2018) and emotion regulation is a further product of self-regulation (Baumeister, & Tierney, 2011). In summary, what is the ultimate effect on the impulsivity in adolescents when they are addicted to exercise? Will the exercise addiction increase their inhibitory control, while the lack of inhibitory control on its own is possibly the cause to their addiction in the first place? This is an interesting line of research that should be investigated.

Furthermore, as mentioned we expected the most of the variable that measured weekly hours spent exercising. This was because literature suggested that more regular exercise would result in less impulsivity (Audiffren, & André, 2015; Crova, et al., 2014; Ludyga, et al., 2016).As the results showed this variable was not significant in neither our cross-sectional nor our longitudinal analysis. In contrast, cardiovascular condition did turn out to be significant in relation to a lower impulsivity. Perhaps it is not the amount of time invested in exercise that has a positive influence on impulsivity, but the quality and intensity of exercise that has an actual effect.

Moreover, from the cross-sectional results, the positive correlation between years invested in exercise and impulsivity could be further explored. This outcome is inconsistent with literature, as it was earlier mentioned that those who exercise longer seem to have lower impulsivity (Ludyga, et al, 2016). Especially when compared to the negative relation between cardiovascular condition and impulsivity this result is somewhat confusing. It is noteworthy that the regression coefficient of this variable was significant with impulsivity, while the correlation was not (p=.350). Furthermore, there was also a negative correlation between cardiovascular condition and years invested in exercise; this outcome is rather puzzling as it would be logical to turn out the other way around. An explanation for this could be that the participants in this sample did show persistence in the participation of their sport, but perhaps did so because of peer relations. Another explanation could be related to sleep/wake behaviours of athletes, a sample of elite athletes was found to be overall sleep deprived (Lastella, Roach, Halson, & Sargent, 2015), of course that study only included elite athletes while we studied amateur exercisers. Another study however confirmed that a sample of amateur athletes in Australia had bad sleep/wake behaviours prior to competitions (Juliff, Halson, & Peiffer, 2014). Likewise, another study found even more negative sleep results in athletes compared to sedentary participants (e.g. problems falling asleep, waking up early) (Demirel, 2016). Thus, this finding could be either explained by a methodological error, sleep deprivation in athletes, or another confounder.

Furthermore, the fact there was no significant effect found in our longitudinal study is a topic that requires further study. This finding was inconsistent with literature, as much articles stated that exercise during adolescence had a beneficial effect on the development of executive functions (Diamond, 2012), especially the development of inhibition (Ludyga, et al., 2016; Crova, et al., 2014), and that especially the areas responsible for these cognitive functions are strengthened (Weinstein, Voss, Prakash, Chaddock, Szabo, et al., 2012). Perhaps this strengthening of cognitive functions does not apply to adolescents up to the point that it counteracts impulsivity at that age.

Lastly, the negative effect of cardiovascular condition on impulsivity could be further investigated by implementing it in school settings by providing the opportunity for students with high levels of impulsivity the chance to invest more time in exercise. This could result in a change in the approach of students who are more likely to disrupt the classroom setting by giving them access to an outlet and a method to increase control over their impulsivity. An explanation for the negative correlation between cardiovascular condition and impulsivity could be that physical exercise enhances neurogenesis (Cotman,& Berchtold, 2002) and that people who exercise more show greater hippocampal and prefrontal volumes (Cotman, Berchtold, & Christie, 2007; Weinstein, et al., 2012; Gearin, & Fien, 2016) as well as greater functional brain connectivity and superior executive and memory functions (Erickson, Hillman, & Kramer, 2015). Furthermore, it was found that epigenetic changes occur when adolescents engage in exercise, which are beneficial for adolescents with ADHD (Abel,&

Rissman 2013). Perhaps those adolescents with a higher condition, experience the benefits of a higher developed and better connected prefrontal cortex, resulting in lowered impulsivity. This idea should be further studied.

Concluding, in our study we found a significant relation between exercise and impulsivity. It has to be specified that our hypothesis has not been met fully. The hypothesis stated that those who exercised more were expected to have lower impulsivity. Here it only appeared that those who had a higher cardiovascular condition had lower impulsivity. Whereas the adolescents who exercise longer have been found to show more impulsivity. This finding could be related to behaviours that co-occur with those people who exercise longer and more serious (e.g. maladaptive sleep/wake patterns) (Juliff, Halson, & Peiffer, 2014; Demirel, 2016). However, to return to the primary aim of this study, impulsivity in adolescence is something that could be influenced positively through exercise. This could have major implications for those who are at high risk of accidents or dangerous health behaviours. Above all, this finding could serve as an extra encouragement for adolescents who feel in need of more control over their thoughts and behaviour. Increase of control does not necessarily have to be found in concentration enhancing medication (e.g. methylphenidate) or therapy (e.g. mindfulness). Involving exercise in the weekly routine already is an effective step towards a stronger grip on your actions and impulses.

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Appendix A – Assumption Statistics Cross-sectional analysis.

To see how the outcomes correlated to our statistical model a reliability analysis was also conducted. It showed a moderate correlation between the predictors and the result (R=.321) and a weak reliability (R^2=.103; R^2_{adj}=.079). Durbin-Watson result was 2.111, so there is some correlation between the model and the error, but it is not strong enough to withhold from continuing our analysis.

VIF results were between 1.174-1.630 and tolerance varied between .613-.852. Together with the fact that there are no linear correlations between the predictor variables it is proven the multicollinearity assumption has been met.

The assumption for normality of errors (see **Figure 3** and **Figure 4**) has also been met. as well as the assumption for homoscedascity.

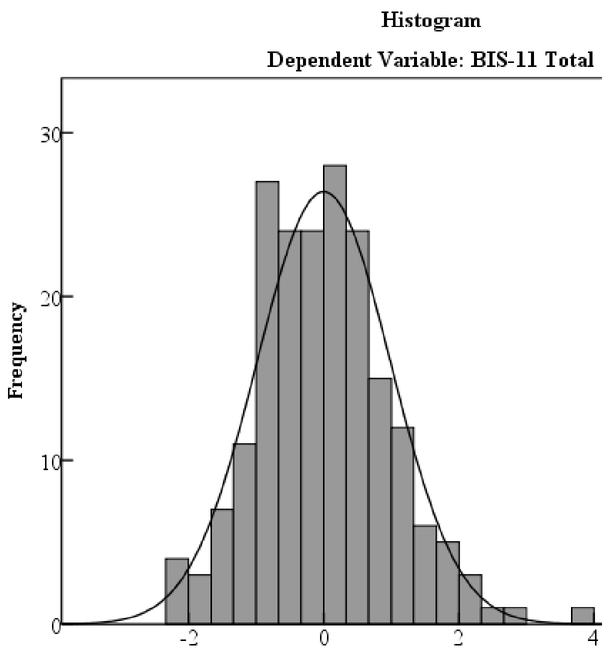

Figure 3. *Distribution of standardized residuals In the cross-sectional study*

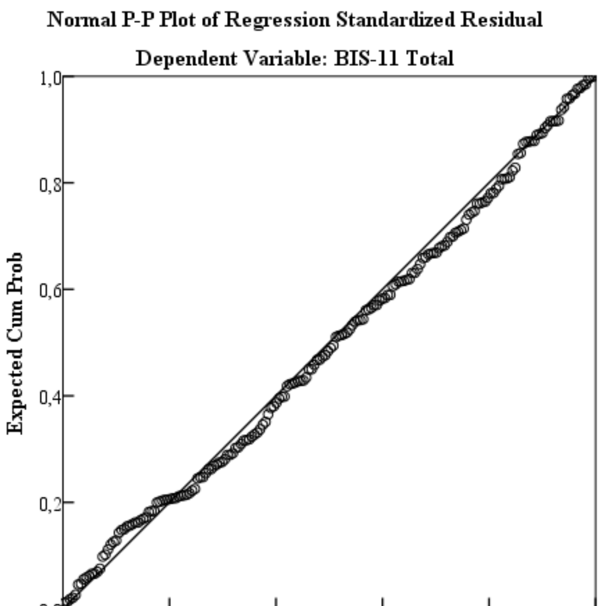

Figure 4. *Normally distributed residuals*

Partial plots showed that also the assumption homoscedascity was met (see **Figure 5-10**). The plot of age shows an almost horizontal but still declining line (R^2=.016). The plot of weekly hours exercised is almost horizontal but still shows a negative relation with impulsivity (R^2=.007). Then the plot of the variable of years invested in exercise shows a positive relation (R^2=.025). The plot of the setting variable is shows the weakest result, with a slightly negative relation (R^2=.000). The plot of cardiovascular condition showed the strongest negative relation to impulsivity and was clearly declining (R^2=.060).

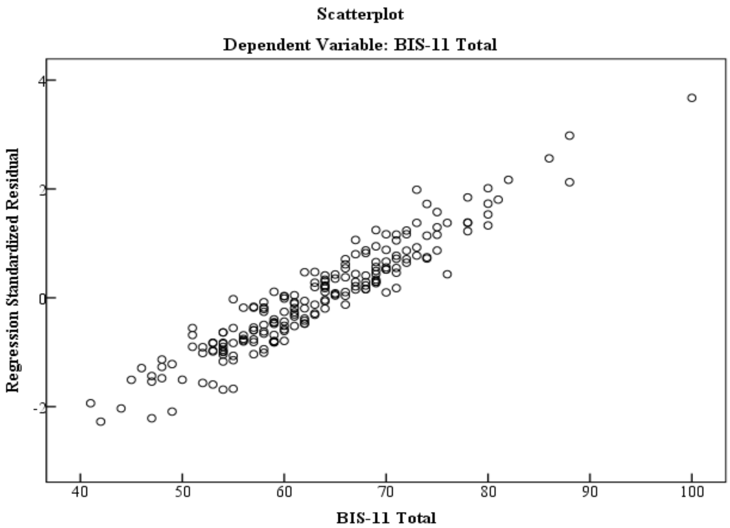

Figure 5. *Partial plot for distribution of impulsivity outcomes*

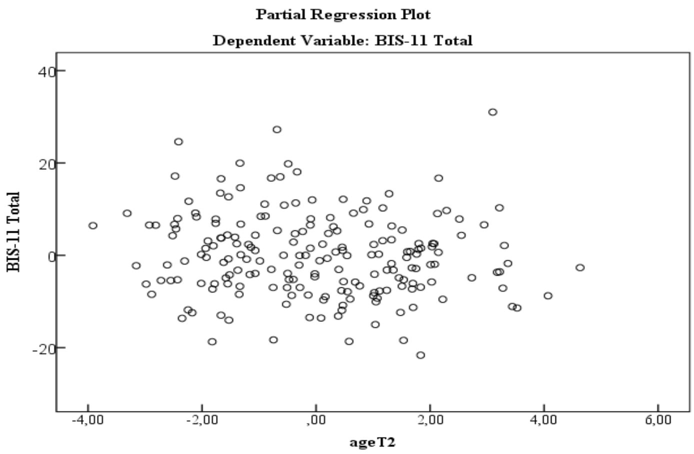

Figure 6. *Partial regression plot for Age on the second time point*

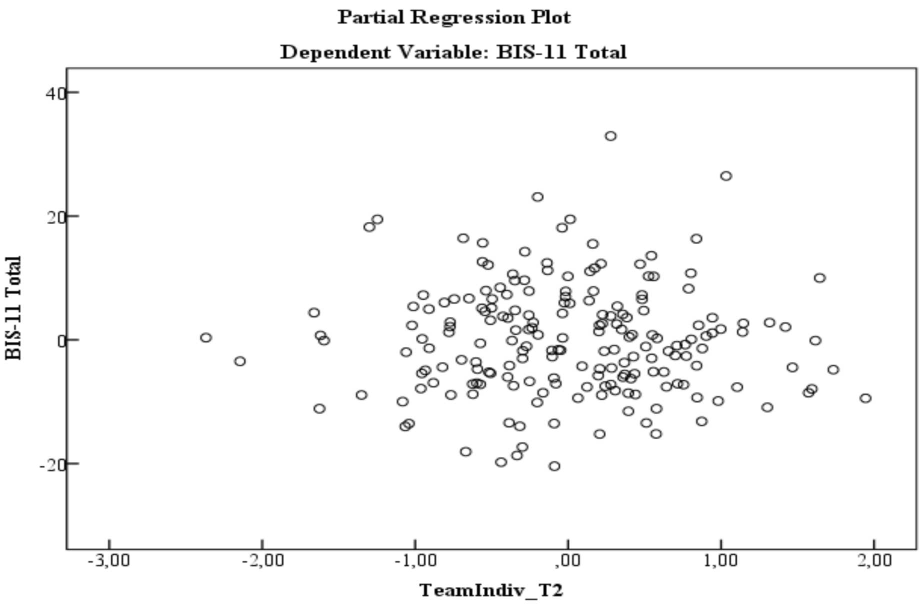

Figure 7. *Partial regression plot for outcomes of the setting variable*

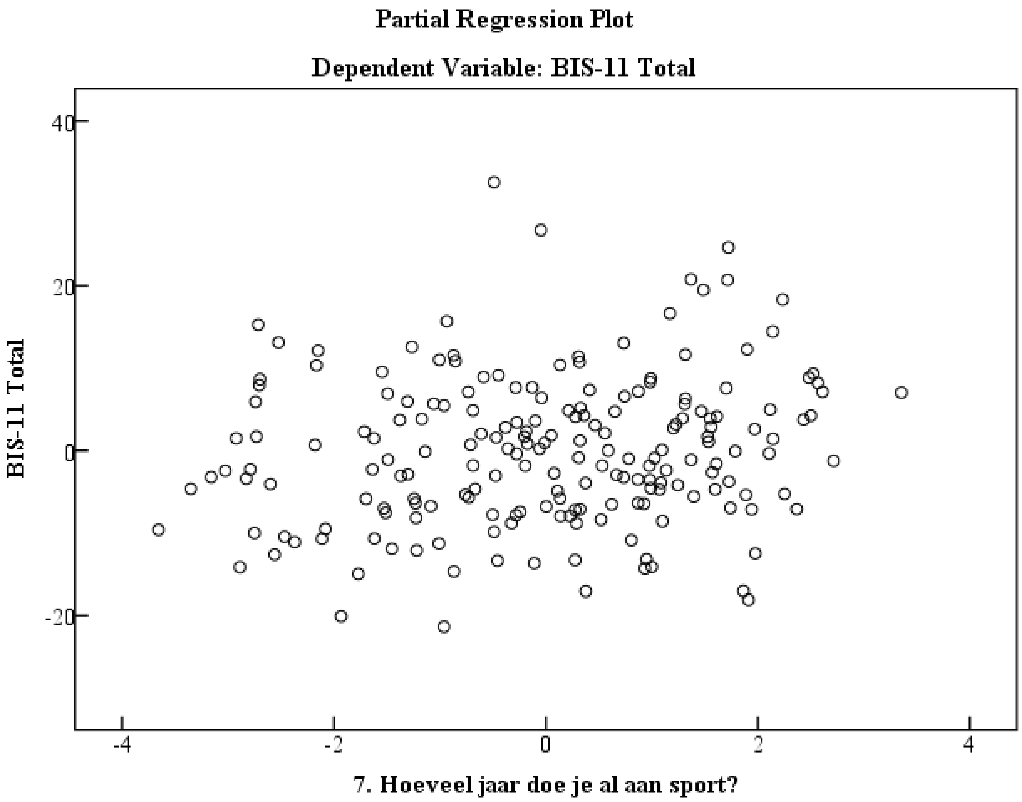

Figure 8. *Partial plot for years invested in exercise*

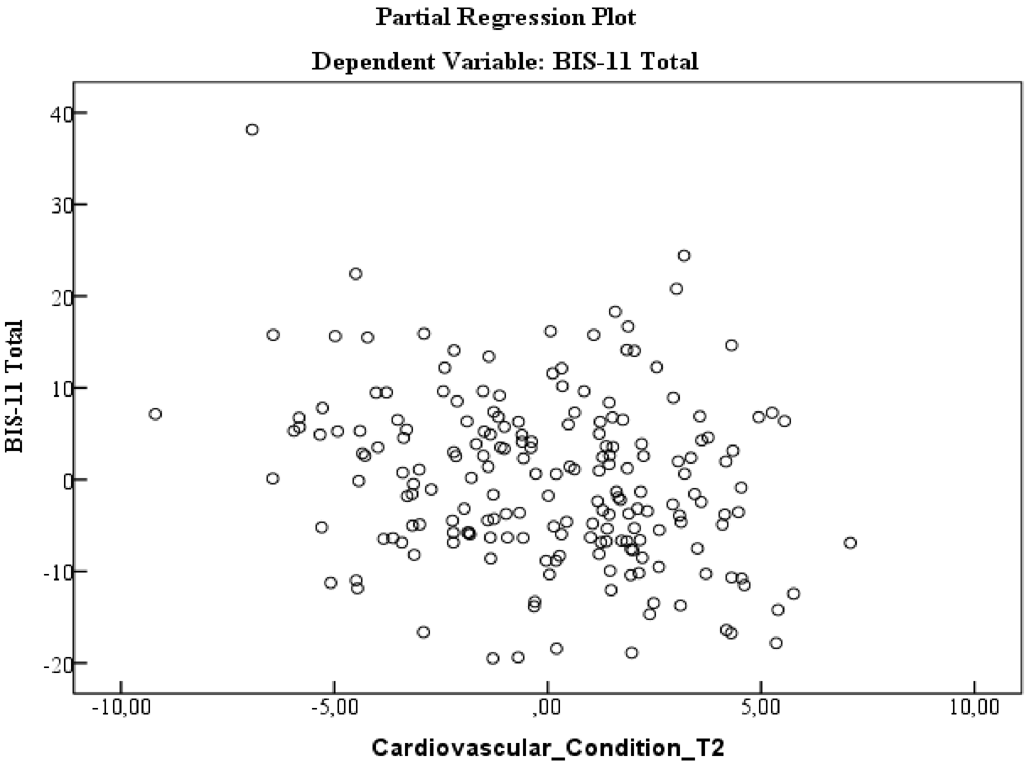

Figure 9. *Partial regression plot for cardiovascular condition*

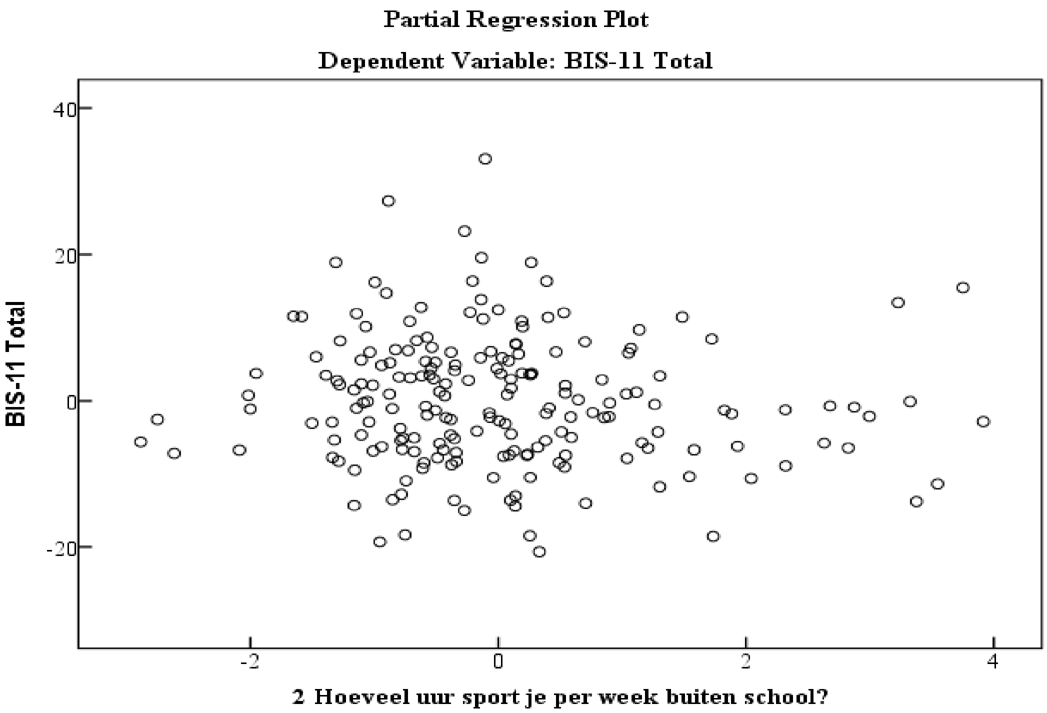

Figure 10. *Partial regression plot for hours weekly invested in exercise*

Appendix B- Assumption Statistics Longitudinal Analysis

VIF results fell in the range of 1,065-1,255. Tolerance was in the range of ,797-,939, but this was high enough to proceed with the analysis. Consultation of the histogram (see **figure 5**) and the PP-plot (see **figure 6**) showed the assumption of normality in this analysis has been met.

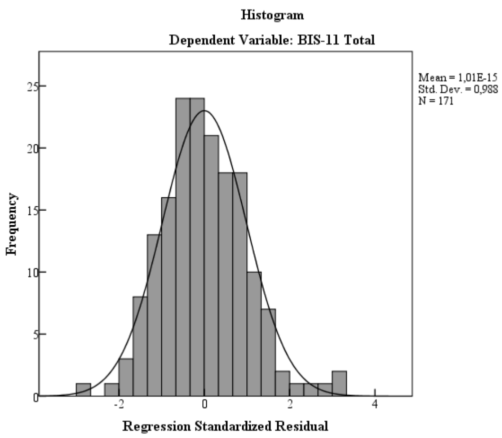

Figure 11. *Distribution of standardized residuals*

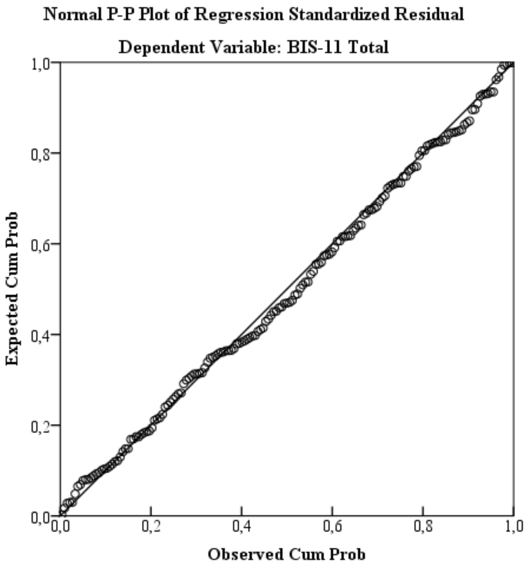

Figure 12. *Normally distributed residuals*

Inspection of partial plots showed that the assumption for homoscedascity was met (see **Figure 13-16**). Age$_{T2}$ showed a negative fit line (R^2=.025). The BIS-11$_{T2}$ data showed a strongly positive fit line with the BIS-11$_{T3}$ data (R^2=.366). Total amount of years invested in exercise had an almost horizontal fit line (R^2=.000) and cardiovascular condition was slightly inclining (R^2=.006).

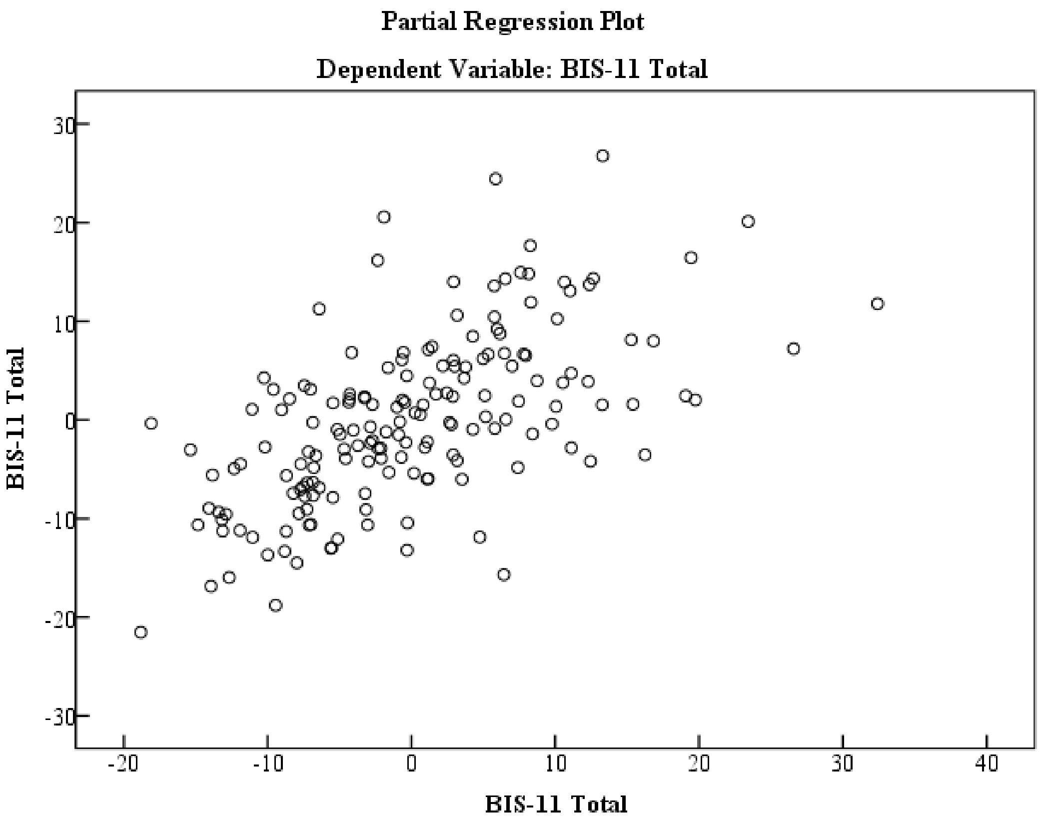

Figure 13.*Partial regression plot of impulsivity*

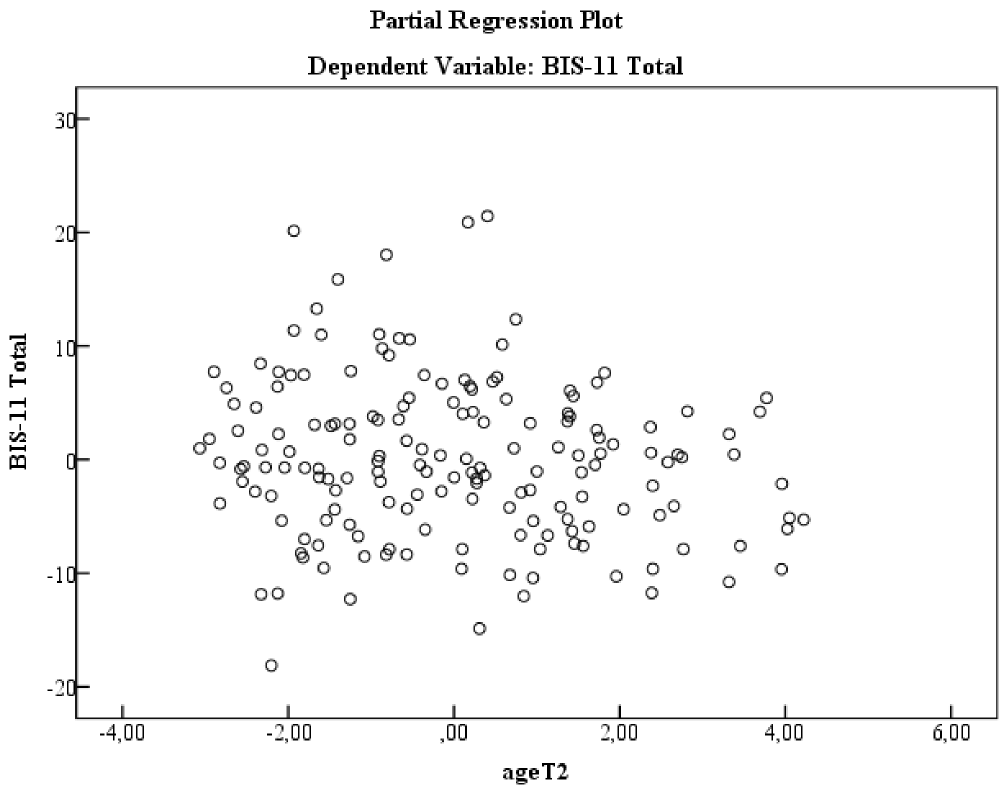

Figure 14. *Partial regression plot for age*

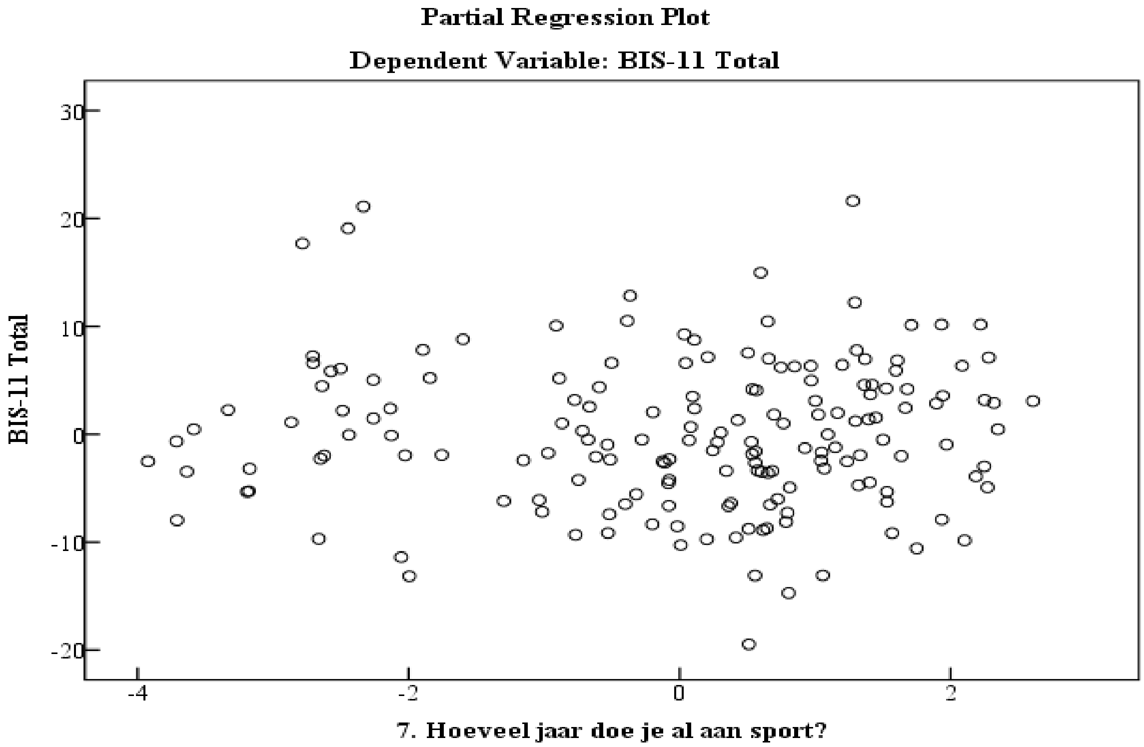

Figure 15. *Partial regression plot for years invested in exercise*

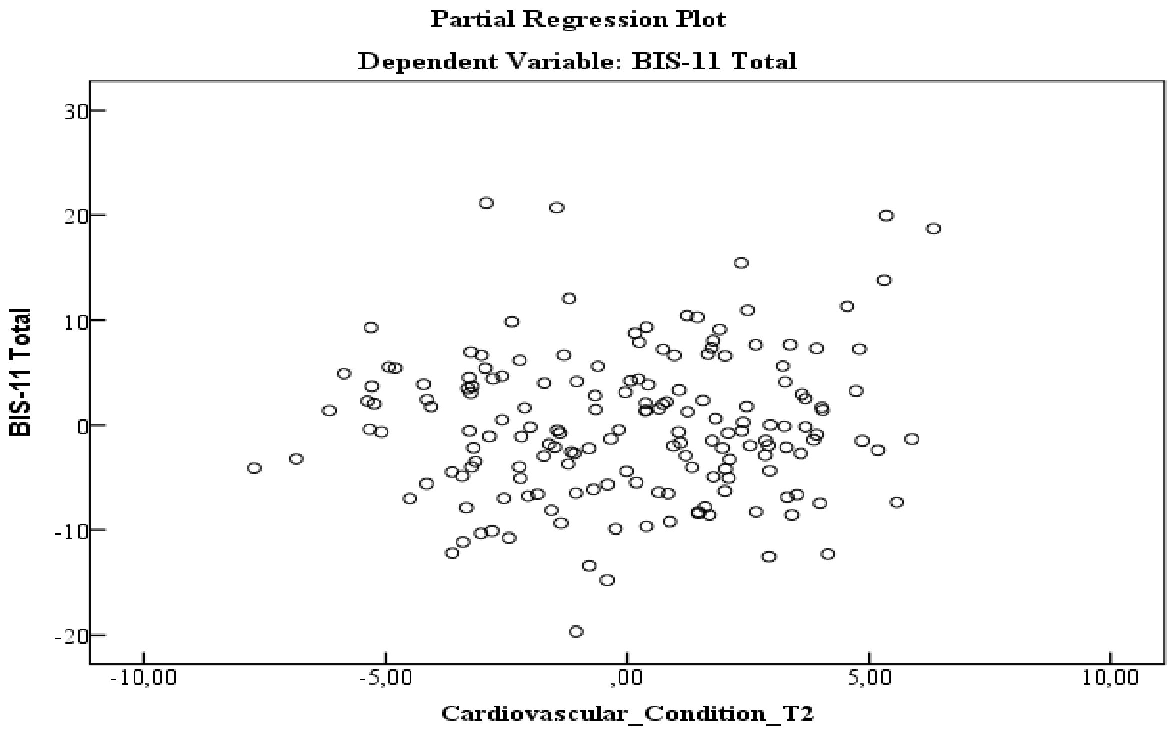

Figure 16. *Partial regression plot for cardiovascular condition*