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Experiences from a randomized, controlled trial on cycling to school: Does cycling increase cardiorespiratory fitness?

Line A B Børrestad[1, 2*]

Lars Østergaard[2]

Lars B Andersen[2, 3]

Elling Bere[1]

[1]Institute of Public Health, Sport and Nutrition, Faculty of Health and Sport, University of Agder, Norway

[2]Center for Research in Childhood Health, Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark.

[3]Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway.

[*] Corresponding author and offprints should be sent to: University of Agder, Department of Public Health, Sport and Nutrition, Service Box 422, No-4604 Kristiansand, Norway.

Phone: 0047 90175474, Fax 0047 38141301, e-mail: line.borrestad@uia.no

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Abstract

Aims:

The objective of the present study was to investigate the effect of a 12-week randomized controlled cycling-to-school trial on cardiorespiratory fitness.

Methods:

A total of 53 ten- to thirteen-year-old children from one public school were included. The children were randomized into either a cycling group or a control group. The cycling group was encouraged to cycle to and from school each day during a period of 12 weeks. Peak oxygen consumption (VO_2peak) and anthropometrical data (weight and height) were measured at baseline and at the end of the 12-week period.

Results:

No significant differences were observed in V02peak change over the 12-week period between the cycling group and the control group; 49.7 mL O_2/min/kg vs. 50.6 mL/min/kg (medium effect size, df=40, F=0.495, p=0.486). Within the intervention group, 65.9% started cycling, and within the control group 48.5% started cycling. At follow-up, a significant difference between those starting cycling and those who did not starting cycling was observed in VO2peak 51.7 mL O_2/min/kg vs. 47.9 mL/min/kg (7.9%, p=0.007) after adjustment for baseline levels.

Conclusion:

This study indicates that cycling to school improves cardiorespiratory fitness.

Keywords: Active commuting, adolescence, children, fitness, public health.

Background

An active lifestyle is associated with beneficial effects on a range of health outcomes and enhancement of well-being (1-3). The relationship between physical activity and different aspects of fitness is convincing (4, 5). Physical activity is also characterized with a high capacity for enjoying life, challenges, improved self-perception and coping strategies in the face of difficulties (3, 6, 7). Low fitness has been associated with a clustering of metabolic risk factors in young people that may persist into adulthood (2, 8). Modifying risk factor levels in young people may thus be of critical importance for ameliorating future cardiovascular-disease (CVD) risk (9, 10). The literature on physical activity levels and fitness in children is inconsistent. While some studies have shown declining levels of physical activity and fitness in school-aged children (11, 12), others failed to do so (13, 14). However, there are concerns about children's health and despite different results, there seems to be little doubt that many adolescents are not active enough for health benefits (15-17), and it is indicated that inactive children can achieve a notable increase in aerobic fitness by increasing their habitual physical activity level (11).

The promotion of physical activity is a public health priority. Many schools and local education authorities have been attempting to promote children's physical activity though schemes to promote active transportation, such as walking and cycling to school (18) . Moreover, numerous studies have addressed active transportation, to promote physical activity in general (19-21), but none have examined the effects of promotion of cycling to school as a specific behavior. Cycling as a mode of transportation appears to be more energy intensive per unit of time, and also seems to benefit health outcomes better, than walking. Shepard (22) calculated that sedentary adults would have to walk for 22 minutes, twice a day, five days a week in order to spend an additional amount of energy sufficient to reduce all-cause and cardiovascular mortality. The same duration for cycling was only 11 minutes per trip. A recent study also show that cycling to school is positively associated with aerobic fitness among children age 9-10-year-old (23), the same results were found for adolescents age 15-year-old (24, 25). Moreover, there is also reported lower rates of overweight in young people cycling to school, compared to those who walk, or who are car or bus commuters (26).

However, in such observational studies causal inferences about cycling to school and fitness cannot be made. In order to state whether changes in cycling to school really have an impact on fitness (and weight status), intervention studies are needed. Such intervention studies on cycling to school have not been conducted previously.

Aims

The aim of the present study was to investigate the effect of a 12-week, randomized, controlled cycling-to-school trial on cardiovascular fitness.

Methods

Study design and sample

This study was a randomized controlled trial. Research clearance was obtained from the Norwegian Social Science Data Services (ID: 22405). The study was conducted and reported in line with, and conformed to the principles embodied in, the declaration of Helsinki(27). Baseline assessment of study variables occurred at recruitment, and follow-up assessment at the end of intervention (12 weeks after the baseline measures).

The present study is part of the project "Active transportation to school and work in Norway (ATN)". Children in the 5th, 6th and 7th grades (n=204) from one school in the Kristiansand community were invited to take part in the study. Inclusion criteria were; age (10-13 years old), health (no physician- identified contraindication for physical activity), cycling (not cycling to school for the last three months, December- February); living less than five kilometers from school, and having access to a bicycle. The recruitment process was carried out between November 2009 and February 2010, and is summarized in fig 1.

The children received information in their classroom about the study, where the aims and implications were explained by the principal investigator (LABB). Afterwards, the children delivered a letter informing their parent/guardian of the study, and written informed consent from the parent/guardian was requested before pupil participation.

Sample size calculation was based on 80% power at a 5% significance level to detect difference between groups of 5% in peak VO_2 with a standard deviation of 0.25. This gave a sample size of 23 within each group. Mean and standard deviation for peak VO_2 was based on data from the Danish study, "Longitudinal associations of cycling to school with adolescent fitness" (25). We assumed that approximately 25 % of children would drop out during the intervention and the recruitment goal was therefore set to 60 (n= 30 per group). In total, 58 children applied to participate in the trial and completed a questionnaire. Out of these, five children lost interest and dropped out of the trial before baseline testing, finally 53 children completed baseline tests.

The children were randomized to either an intervention group (IG) or a control group (CG) by a research investigator using a computerized randomization program: 27 children in the CG (of which five dropped out in the study period) and 26 children in the IG (of which two dropped out in the study period). The principal investigator was not involved in testing the children and was blinded to group allocation while assessing the outcome measures and plotting the data. The mean age of the children was 10.9 years, and 53 % were boys. Further descriptions of the samples are presented in Table 1.

Intervention program

The cycling group was encouraged to cycle to and from school on each school-day during a period of 12 weeks from March to May in 2010. The weather conditions in Norway differ significantly throughout the year. In March the local average temperature is 1.3°C and the length of the day according to sun rise and sun set is 12.5 hours vs. 10.2°C and 17.5 hours daylights in May. The cycling conditions are supposed to be good throughout these months.

The researcher primarily facilitated the intervention; however, school staff and a specialist in cycling safety and parents were also involved. The intervention program was performed at school during school hours in group sessions every second week, resulting in a total of six group sessions. Each session lasted approximately 30 minutes. When motivating children to cycle to school we focused on raising awareness, countering passive transport and helping parents support. Moreover, we focused on health benefits from physical activity, especially cycling, and also road safety issues, including co-operation with the Norwegian Council for Road Safety. All parents/guardians for the intervention group were invited to a session at baseline focusing on information and encouraging cycling to school. Furthermore, all parents/guardians for the whole study group (intervention and control group) received four letters throughout the study providing information about the study.

Measurements

Data collection was identical at baseline and at the end of the intervention period. All the measurements were pilot tested in order to resolve potential logistical issues. The investigator trained research assistants to provide all the measurements. The primary outcome was cardio-respiratory fitness (CRF). We also collected anthropometrical and questionnaire data at the same time as the primary outcome.

Cardio respiratory fitness (CRF)

The primary outcome, CRF (maximal power output per kilogram; W max kg-1) was determined using an electronically braked cycle ergometer (Monark 839 ergomedic). The test protocol was validated and designed to assess maximal aerobic power in children (16) After three minutes' warm-up, participants pedaled at 60-80 rpm with the workload increasing every minute until exhaustion.

Initial workloads for the ten-year-old children were 20 watts for children weighing less than 30 kg and 25 watts for children weighing 30 kg or more. The eleven-year-olds' initial workloads were 30 watts for children weighing less than 40 kg and 35 watts for children weighing 40 kg or more, and for the twelve-year-olds initial workloads were 40 watts for children weighing less than 50 kg and 45 watts for children weighing 50 kg or more (24). Incremental workload was 10 watts every minute until exhaustion for all age groups. Heart rate was recorded continuously throughout the test using a heart rate monitor (Polar Vantage, Polar Electro, Kempele, Finland). Criteria for exhaustion were either a heart rate above 185 beats per minute, failure to maintain a pedaling frequency of at least 60 rpm or a subjective judgment by the observer that the individual could no longer continue (19). CRF was defined as maximal power output per kilogram (MPO; Wmax x kg^{-1}). The Peak VO_2 was calculated according to the following formula published by Kolle and colleagues (16):

10- and 11-year-olds: (VO_2 peak L/min) = 0.452 + (0.0108 x Wmax) + (0.033 x sex)

12-year-olds: (VO_2 peak L/min) = 0.465 + (0.0112 x Wmax) + (0.172 x sex)

(Sex =0 for girls; Sex= 1 for boys).

The maximal power output was calculated for each individual according to the formula: W1 + (W2 x t/180) where W1 = workload in watts at last completed stage, W2 = the workload increment in watts at the final incomplete stage, and t = time in seconds at the final incomplete stage (16). Cycle ergometry is a reliable method of estimating maximal oxygen uptake (VO_{2peak}) in children with an intra-class correlation of 0.96 (28), and MPO is highly correlated with VO_{2peak} in children aged 9-15 years (r>0.90) (29).

Body composition

Height was measured to the nearest 1 mm with a Harpenden stationmeter, and weight was measured to the nearest 0.1 kg using a calibrated beam scale (Seca model 713) while the participants wore light clothing and no shoes. Body mass index (BMI) was calculated as weight (kg)/$height^2$ (m). Normal weight or overweight were defined according to the criteria of the International Obesity Task force (IOTF), which use age- and sex-specific cutoff points (30).

Questionnaire

All children completed a questionnaire to assess inclusion criteria, demographic information (e.g. age, gender) and commuting behavior at baseline and at the end of the intervention. The participants were asked in a matrix how many days a week they traveled to/from school the last 3 months by (1) walking; (2) cycling, (3) car; or (4) public transport (31). Children who had not cycled to school during the last three months (i.e. the winter months) were included in the study. To assess commuting behavior throughout the intervention period, all participants refilled the questionnaire matrix at the end of the intervention. Distance from home to school was calculated from the pupil's home address using the length of the "optimal route by foot" option within http://maps.google.no in November 2009.

Statistical analyses

Descriptive statistics (means and standard deviations) were calculated for all variables using PASW 18 (Predictive Analytics Software) and STATA IC 10 (StataCorp, College Station) in June 2011. The intervention effect was defined as the difference between intervention and control groups at follow-up, adjusted for baseline level, as recommended by Twisk (32). Mixed models, adjusted for baseline scores gender and age, were conducted with follow-up measurements of VO_2 peak, HR, BMI and weight status as dependent variables, including respective baseline measurement, gender, age and group as independent variables. Re-analyses of the data were conducted in order to compare cycling relative to non-cycling participants irrespective of randomized groups. Spearman´s rank order correlation was used to estimate the rank order agreement between cycling to school and distance. The magnitude of the overall effect was explained through the magnitude of the standardized effect size (ES) for the F statistic, difference/SD(33). Degrees of freedom (N-1) is the same in all analyses, df=51, for the differences between intervention and control group; in the re-analyses of the data, df=44.

Results

There were no statistically significant baseline differences between control and intervention groups for any of the outcome variables, or for gender and age (Table 1). No significant effect of the intervention was observed (Table 2). The differences between the intervention and the control groups at follow-up, adjusted for baseline level, were respectively for peak VO_2: 49.7 mL O_2/min/kg vs. 50.6 mL/min/kg (ES=-0.13, F=0.495, p=0.486), maximal HR during the cycle test: 193.5 beats/min vs. 193.2 beats/min (ES=0.03, F=0.013, p=0.909), BMI: 18.8 kg m^{-2} vs. 18.6 kg m^{-2} (ES=0.01, F=0.849, p=0.362) and weight status: 20.8.2% (CI= 8.0- 33.7) vs. 21.2% (CI=7.7- 34.6) overweight (Table 2). The intervention had neither any significant impact on cycling to school, since several children in both groups (intervention and control) reported to cycle during the intervention period in spring 2010, hence 69.2 % (CI=50.1- 88.2) in the intervention group reported to start cycling vs. 40.8% (CI=20.9- 60.5) in the control group.

Given that several children in both groups (intervention and control) started cycling to school, re-analyses were conducted between those starting cycling and those not starting cycling. In the full study sample (n=46), 60.9% (CI= 46.2- 75.5) of the children started cycling to school. At baseline there was no significant difference between those starting cycling and those who did not, in any variables at baseline (Table 3). At follow-up, a significant difference between those starting cycling and those not starting cycling were observed in VO_{2peak} 51.7 mL O_2/min/kg vs. 47.9 mL/min/kg (ES=0.49, F=8.145, p=0.007), after adjustment for baseline levels (table 4). There were no statistically significant differences in maximal HR during the max cycle test (194.7 vs. 191.2 beat/min, (ES=0.41, F=1.972, p=0.168), BMI (18.6 vs. 18.8 kg/m^{-2} (ES=-0.01, F=0.25, p=0.391) or weight status (18.5% CI= 6.6-30.5 vs. 24.5%, CI= 10.8- 38.3), between those starting cycling and those not starting cycling at follow-up, adjusted for baseline level (Table 4). Moreover, no significant results between groups in distance between home and school were found (Spearman´s correlation coefficient=0.143, p=0.306).

Discussion

We found no significant difference in VO_{2peak} over the 12-week period between the intervention group and the control group in the present randomized controlled study. Neither did we see a difference in the proportion of pupils starting cycling in the two groups. However, several children in both groups (intervention and control) reported having started cycling to school during the trial. This could be due to the recruitment process for participating in the study and a strong and well- developed cycle culture in Norway. We included children who had not cycled to school for the last three months (i.e. the winter months), and several of them usually cycle in spring and fall when the weather conditions is well-prepared for cycling. Ideally, inclusion criteria should have been restricted to children who never cycle to school at any time during the year.

Re-analyses of the data showed that those who cycled to school during spring 2010 (i.e. the "starting cycling" group) increased VO_{2peak} with 7.9% compared to those not cycling to school during this 12-week intervention period. This result is in line with existing literature showing that cycling to school is associated with high levels of aerobic fitness (24, 25). Andersen and colleagues (24) found that the maximal work capacity was 5.9% higher in boys, and 4.6 % higher in girls cycling to school, compared to those adolescents who used passive transport (aged 15-19- years old). They also found that children who cycled to school had higher muscle endurance and flexibility than children who walked or were driven to school. A longitudinal Danish study on cycling to school found that children (aged 9.7 years) not cycling to school at baseline, but who had changed to cycling at follow-up six years later, were significantly fitter than those who did not cycle to school at either point, a difference of 9% (25). The present study adds to the literature showing that children starting cycling to school in the spring improved fitness only after 3 months of cycling to school, compared to those not starting cycling.

However, the majority of those who started cycling during the intervention period also cycled to school during the previous spring; 89.7% (CI= 77.9-101.4) vs. 45.8% (CI= 24.3- 67.3) respectively for those not cycling during the intervention (p=0.001). Besides that they cycle to school this group might differ from those not cycling also in other respects. In example children's pattern of physical activity is related to parent's physical activity pattern. In example children's pattern of physical activity is related to parents physical activity pattern (34). Cycling to schools might therefore reflect other factors, like parent's attitude towards physical activity, or parents' socio-economic status (26). Moreover, the children cycling to school had a lower mean BMI, possibly in part because they commuter-cycle most of the school year, except for the winter months.

Increasing levels of physical activity and fitness in children is considered to be a public health priority, but how best to do this is not clear. Commuter cycling appears to be a more intensive form of exercise than commuter walking (22). Therefore, the present results support previous suggestions that the exercise intensity of the active commuting mode may play a role in the strength of the association between travel mode and aerobic fitness (24, 25, 35). The intensity of commuter cycling in children is unknown, but repeated bouts of 10 to 20 minutes of exercise at 80-85% of HR_{max} can significantly increase peak VO_{2max} (36). Consequently, it has previously been assumed that if the intensity of commuter cycling to school approaches this level, even for short bouts, this could explain why daily cycling to school improves CRF

(25). On the other hand a 10-to-15 minute bout of regularly bicycling twice a day has been suggested to be sufficient to increase aerobic power in children (24). The association between travel mode and fitness has often been appreciated as a consequence of selection bias. The post-hoc analyses of the present study, however, suggest that cycling to school does in fact improve CRF. Therefore, future public health strategies should promote cycle-friendly environments, like cycle trails and traffic- lights that enhance the attractiveness and amenity of cycling commuting for children and young people. Schools and local educations should reinforce and continue to promote children’s walking and cycling to school, through a greater emphasis on health in the curriculum and through schemes to promote active transport.

The major strength of this study is the randomized, controlled design. However, randomized, controlled trials (RCTs) are time consuming, and involve a great deal of co-operation from participants. There are also some factors that may have limited the validity. One major limitation with the present study is that the intervention did not impact frequency of cycling to school, turning the rigidly designed RCT into a longitudinal cohort study. We included children who had not cycled to school for the last three months (i.e. the winter months), and several of them usually cycle in spring and fall. Ideally, one of the inclusion criteria should have been that the participants included in this study, should be children who never before cycled to school.

Regarding, that children in the control group behave as if they were in the treatment group and the opposite behavior was also observed in the treatment group; may be explained by differences with respect to motivational states (Ryan and Deci 2000)”. Participants in this study who started to cycle to school may had conditions that facilitate the natural process of self- motivation on cycling to school. This non-compliance phenomenon was probably a major reason to less effect size between control and intervention group. Moreover, all participants in the study came from one school and many of them shared the same group class, therefore we suspect that the interaction between children in the control and intervention groups may have influenced behavioral change. Likewise, both groups received detailed information regarding the aims and implication of the study, before and during the intervention in regard to fulfill the ethical guidelines. Maybe to secure against finally interdependence in individual-based randomized studies on active commuting, the most appropriate design for future studies ought to be stratified to school randomization. In addition, objective and accurate quantification of the amount of cycling would have been useful to assess the effect of intervention. Indeed, cycling data were collected, but due to several measurements problems with the cycle computer, these data are lacking in the trial presentation. In order to tackle this issue, future studies might choose to measure cycling throughout continuous follow-up system to provide reliable data.

Conclusion:

This study indicates that cycling to school improves cardiovascular fitness; however, more knowledge is needed about how cycling is best promoted.

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Table I. Participant`s characteristics by intervention and control groups at baseline (T1), mean (SD).

		Intervention (n=26)	Control (n=27)	*p-value
Age	year	10.8 (0.7)	10.9 (0.7)	0.274
Gender	Boys, %	53.9	51.9	0.884
Height	cm	150.5 (8.0)	150.3 (9.5)	0.521
Weight	kg	42.8 (8.5)	41.9 (8.6)	0.649
BMI	kg/m^2	18.8 (2.5)	18.4 (2.4)	0.288
Weight status	overweight, %	30.8	4.8	0.165
HR Peak	hr/min	192.3 (9.4)	194.4 (7.8)	0.185
VO_2 Peak	mL/min/kg	46.3 (7.1)	46.5 (7.5)	0.454
Distance to school	KM	1.5 (0.6)	1.6 (0.6)	0.260

*All comparisons of continuous variables are t-test; comparisons of dichotomous variables are chi-square analyses.

Table II. Adjusted* means, SD (CI) and effect size of intervention and control groups at baseline (T1) and after the 12- week cycle to school intervention (T2) during a period from March- May, 2010 (n=53).

		T1					T2*					T2*				
Variable	Group	Crude mean n=53	SD	(CI)		ES	Crude. mean n=53	SD	(CI)		ES	adj. mean n=53	SD	(CI)		ES
Vpeak VO2	Intervensjon	46.3	7.5	(43.5	49.2)	-0.03	48.3	8.0	(44.9	51.7)	-0.32	49.7	5.2	(47.5	51.8)	-0.13
	Control	46.5	7.1	(43.6	49.5)		50.6	7.1	(47.4	53.7)		50.6	5.0	(48.5	52.8)	
	p-value	0.454					0.159					0.486				
HR peak	Intervensjon	192.3	9.4	(188.5	196.1)	-0.24	193.0	9.5	(189	196.9)	-0.20	193.5	9.8	(189.4	197.5)	0.03
	Control	194.4	7.8	(191.4	197.5)		194.8	12.1	(189.4	200.2)		193.2	9.3	(189.2	197.2)	
	p-value	0.185					0.281					0.909				
BMI	Intervensjon	18.8	2.5	(17.8	19.7)	0.02	19.3	2.4	(18.3	20.3)	0.06	18.8	0.8	(18.5	19.1)	0.01
	Control	18.4	2.4	(17.4	19.3)		18.2	1.9	(17.3	19.0)		18.6	0.8	(18.3	13.9)	
	p-value	0.712					0.948					0.362				
Overweight	Intervensjon	30.8%		(11.8	49.8)		33.3%		(12.9	53.7)		20.8%		(8.0	33.7)	
	Control	14.8%		(0.4	29.3)		9.5%		(-4.2	23.2)		21.2%		(7.7	34.6)	
	p-value	0.914					0.971					0.970				

* Linear mixed model adjusted for baseline scores gender and age

** For the continuous variable, mean, standard deviation, confidence intervals, p-values and effect size are given

*** For the categorical variable, chi square, confidence interval and p- values are given

Table III. Participant's characteristics by children cycled to school and children not cycled to school at baseline (T1), mean (SD).

		Cyclists (n=29)	Non- cyclists (n=24)	p-value
Age	year	10.8 (0.7)	11.0 (0.8)	0.556
Gender	Boys %	58.6	45.8	0.353
Height	cm	149.7 (8.6)	151.2 (8.9)	0.272
Weight	kg	40.7 (8.3)	44.3 (8.4)	0.065
BMI	kg/m^2	18.0 (2.3)	19.2 (2.3)	0.064
Weight status	Overweight %	17.2	29.1	0.302
HR Peak	hr/min	194.3 (8.3)	192.3 (9.1)	0.790
Vo_2 Peak	mL/min/kg	48.2 (7.0)	44.3 (7.1)	0.976
Distance to school	KM	1.6 (0.7)	1.5 (0.6)	0.847

*All comparisons of continuous variables are t-test; comparisons of dichotomous variables are chi-square analyses.

Table IV. Adjusted* means, SD (CI) of children cycled to school and children not cycled to school at baseline (T1) and after the 12- week cycle to school intervention (T2) during a period from March- May, 2010 (n=46).

		T1					T2					T2*				
Variable	Group	Crude mean	SD	(CI)		ES	Crude mean	SD	(CI)		ES	adj. mean	SD	(CI)		ES
		n=46					n=46					n=46				
Peak VO2	Cyclist T2	48.2	7.0	(45.6	50.9)	0.54	52.2	7.5	(49.3	55.1)	1.00	51.7	4.6	(49.8	53.6)	0.49
	Non-cyclists T2	44.3	7.1	(41.3	47.3)		45.0	5.5	(42.3	47.7)		47.9	5.2	(45.6	50.1)	
	p-value	0.976					**0.001***					**0.007***				
HR peak	Cyclist T2	194.3	8.3	(191.1	197.4)	0.23	196.3	9.5	(192.6	199.9)	0.72	194.7	8.9	(191.1	198.4)	0.41
	Non-cyclists T2	192.3	9.1	(188.5	196.2)		190.1	11.7	(184.3	195.9)		191.2	10.0	(186.9	195.5)	
	p-value	0.790					0.971					0.168				
BMI	Cyclist T2	18.0	2.3	(17.1	18.9)	-0.06	18.3	2.2	(17.4	19.1)	0.06	18.6	0.7	(18.3	18.9)	-0.01
	Non-cyclists T2	19.2	2.3	(18.2	20.2)		19.5	2.1	18.4	20.5		18.8	0.8	(18.4	19.1)	
	p-value	**0.003***					**0.040***					0.391				
Overweight	Cyclist T2	17.2%		(2.6	31.8)		18.5%		(2.9	34.2)		18.5%		(6.6	30.5)	
	Non-cyclists T2	29.1%		(9.6	48.8)		27.8%		(4.9	50.7)		24.5%		(10.8	38.3)	
	p-value	0.155					0.238					0.458				

* Linear mixed model adjusted for baseline scores gender and age

** For the continuous variable, mean, standard deviation, confidence intervals, p-values and effect size are given

*** For the categorical variable, chi square, confidence interval and p- values are given