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Research article

Changes in Digital Media Use and Physical Activity in German Young Adults under the Covid-19 Pandemic - A Cross-Sectional Study

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Abstract

Many studies observed a reduction of physical activity (PA) and an increase in digital media use in young adults during the COVID-19 pandemic. However, few studies have been conducted in Europe or looked at changes in the association between both behaviors. Hence, this study aims at investigating the changes in digital media use/social media use and PA as well as in its association among young adults in Germany. Cross-sectional data of 884 German young adults (mean age 22.36 (±1.99), 76% female) collected via an online questionnaire between August 1 and September 30, 2020 were analyzed. Participants reported on digital media use (smartphone, television, computer, gaming console), social media use (Facebook, Instagram, Snapchat, Twitter, YouTube, TikTok) and PA (days/week of ≥30 min. PA) separately for the period of strict infection control measures in Germany (March - end of May 2020) and for normal times (before March 2020). Descriptive statistics of digital media use, social media use and PA were compared between both periods. Linear regression adjusted for sociodemographic and work-related characteristics were conducted for both periods with total media use, the various media devices and social media use, respectively, as independent and PA as dependent variables. Whereas PA did not differ between both periods, mean total digital media use increased by 1 hour during the period of strict infection control measures. Digital media use and social media use were negatively associated with PA in both time periods. Differences in these associations by sex could be found for some digital media devices. However, 60% of respondents did not comply with the WHO recommendations for PA. Under consideration of possible recall bias, young adults' digital media use, but not PA, seemed to have changed under the strict infection control measures. However, interventions are needed to increase PA and to prevent its reduction in the course of the pandemic.

Key words: Screen time, social media, exercise, COVID-19, young adults.

Introduction

COVID-19 has a major impact on the individuals and society (Nicola et al., 2020; Singh and Singh, 2020). To protect people's health and to reduce the spread of the COVID-19 virus, the German government - as did most other countries around the world - imposed several measures restricting people's movement (Die Bundesregierung, 2021; Roser et al., 2020). In mid-March 2020, cultural-, recreational- and sport institutions as well as catering and restaurants were closed, and social contact restrictions were imposed as social distancing measures (Robert Koch-Institute (RKI), 2020a). Later, people were also ordered to use face masks when using transportation services and going shopping (RKI, 2020b). Over the time, the measures were regularly evaluated and adjusted (RKI, 2021). These strict measures were gradually lifted from the end of May.

The restricted everyday life not only affects the social interaction (Ammar et al., 2020), but also the individual health behaviors (Ammar et al., 2020; Rolland et al., 2020). People are more likely to have a less active lifestyle than they had before COVID-19, as they stay at home more often, do more sedentary work and have fewer opportunities to exercise (Alomari et al., 2020; Ammar et al., 2020; Colley et al., 2020; Meyer et al., 2020). In addition, screen time and media use has increased (Jia et al., 2020; Keel et al., 2020; Qin et al., 2020). Qin et al. (2020), for instance, examined the effects of COVID-19 on the screen time among adults (18-80 years old) from China. Overall, mean screen time was 262.3 ±189.8 minutes per day with significant higher screen time for young adults (20-29 years) (305.6 ± 217.5 min per day). Furthermore, Qin et al. (2020) showed that young adults (20-34 years) had a lower level of physical activity (PA) during the COVID-19 pandemic than older adults. Current studies show both a positive and a negative association between digital media use and PA. For example, higher video gaming (Ballard et al., 2009) and smartphone use (Grimaldi-Puyana et al., 2020) is associated with a lower likelihood of daily exercise. In contrast, the use of social media, especially sports content such as "fitspiration" posts, can act as a motivator for PA (Raggatt et al., 2018; Shimoga et al., 2019; Vaterlaus et al., 2015). Furthermore, Kenney and Gortmaker (2017) suggest that there are differences in the association of digital media use and PA between men and women. Keel et al. (2020), for example, indicate that women had a greater increase in social media use than men who, in turn, had a greater increase in gaming than women during the COVID-19 lockdown. In summary, restrictions that are supposed to protect the people's health simultaneously increase the prevalence of health damaging behavior. For instance, pandemic-caused worries and a concurrent decline in PA is associated with several physical and psychological health problems, such as cardiovascular diseases (Mattioli et al., 2020), obesity (Jia et al., 2020; Keel et al., 2020), depression, anxiety, and mental illness (Huckins et al., 2020; Meyer et al., 2020; Qin et al., 2020). However, there is very little evidence assessing the impact of COVID-19 infection control measures on digital media use and PA among young adults in Europe.

Consequently, the aim of this study was to assess the differences in digital media and social media use during

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the period of the strict infection control measures in Germany (March until the end of May 2020) and the time before March 2020 (in normal times) among German young adults. In addition, the association of digital media/social media use and PA during the period of strict infection control measures and during normal times was examined. In accordance with current research, this study tested for an interaction by sex on the association of digital media use and physical activity.

Methods

Study Sample

The study sample comprised young adults in Germany between 18 and 26 years. Based on Grimaldi-Puyana et al. (2020) we performed a sample size calculation, that yielded a minimum sample size of 430 to find an effect of $\beta = -0.16$ with a precision of $\alpha = 0.05$ and a power of 80%. The participants were recruited via social media (Facebook, Instagram), mailing lists of universities in Germany as well as among acquaintances.

Data collection

Cross-sectional data of the participants were collected anonymously during the 1st of August and the 30th of September 2020 using an online questionnaire on the platform SoSci Survey (Leiner, 2019). The questionnaire was available in German and English and its completion took about 10 to 15 minutes. All respondents gave their informed consent to voluntarily participate in the study and to use their data for research purposes before they started with the questionnaire. This study was conducted in accordance with the Declaration of Helsinki.

Digital media use

General digital media use was assessed with the questions *"How many hours per day did you use following devices in your free time during the period of strict infection control measures (March to the end of May 2020)?"* and *"How many hours per day did you use following devices in your free time during normal times (before March 2020)?"*. Answers were collected for the devices smartphone, television, computer/laptop/tablet and gaming console for weekends and weekdays separately. The answer categories were *never, under 1 hour, 1 - < 2 hours, 2 - <3 hours, 3 -< 4 hours* and *4 or more hours*. Along with Braig et al. (2018) and Lampert et al. (2007), information on weekends and weekdays were combined for the analysis by weighting the mid-values of the selected category for weekday and weekend day (0 hours = 0; under 1 hour = 0.5; 1 - <2 hours = 1.5; 2 - <3 hours = 2.5; 3 - <4 hours = 3.5 and 4 or more hours = 5), summing them up and dividing them by 7 days ((category mid-value weekdays*5 + category mid-value weekends*2)/7). As a result, a score was generated indicating the use (in hours) of the specific devices on an average day. Based on this score the variable total media use was derived by summing up the use of all devices. Additionally, social media use was measured with the questions *"How many hours per day did you use following social media in your free time during the period of strict infection control measures (March to the end of May 2020)?"* and *"How many hours per day do you use following social media in your free time during normal times (before March 2020)?"*. Answers were collected for the social media platforms most used by young adults (Hruska and Maresova, 2020): Facebook, Instagram, Snapchat, Twitter, Pinterest, YouTube, TikTok. The same answer categories as above applied, but information was not collected for weekends and weekdays separately. By summing up the categories' mid-values of each social media platform, the variable total social media use was calculated. On account of the limited scope of this research article we examined total social media use instead of the individual social media platforms separately.

Physical activity

In the style of Milton et al. (2011), a validated and reliable (Milton et al., 2011; 2013, Wanner et al., 2014) single-item question was used to measure the respondents' PA: "*On how many days have you done at least 30 minutes or more of physical activity which was enough to raise your breathing rate? This takes into account both sport and physical activity such as brisk walking or cycling to get from A to B (e.g. way to and from work)."* Valid responses ranged from 0 days to 7 days on an open response scale. Answers were collected for the period of strict infection control measures and for normal times separately. We also derived the binary variable PA guidelines that indicated whether or not the respondent adhered to the PA guidelines according to the World Health Organization (WHO, 2010) and the German national recommendation (Rütten and Pfeifer, 2016), that is 5 or more days per week of at least 30 minutes PA that elevates the breathing rate (Wanner et al., 2014). In addition, physical exertion at main occupation (sitting activity without physical exertion, sitting with some physical exertion, standing or walking activity without physical exertion, standing or walking activity with some physical exertion and manual, physical (very) demanding activity) was asked.

Covariables

In consideration of current literature, possible confounders and effect modifiers were identified and assembled in a theory-based "association model" (we did not draw up a directed acyclic graph (DAG) due to the cross-sectional nature of our analysis; further explanation in supplementary material S1a and S1b). These included basic socioeconomic variables, such as biological sex assigned at birth (male, female), age in years, high school leaving degree (recoded into high school diploma (German "Abitur") vs. lower), highest vocational degree (no degree yet, vocational training, college/university degree (Bachelor, Master), technical college/school degree) and financial coping (very good, good, with minor difficulties, with difficulties, with major difficulties and I do not know). Further covariables were measured for the period of strict infection control measures and for normal times separately. These comprised the main occupation (school, university, apprenticeship, employed, unemployed, internship and else), working hours (0 - <20, 20 - <30, 30 - <40 and 40 and more hours), second job (yes, no), and cohabitation (alone, with others), changes in free time and in time caring for other persons during the period of strict infection control measures (more time, no change, less time and no caring). Furthermore, additional variables such as community size (large metropolis (≥500,000 inhabitants), small metropolis (100,000 to <500,000 inhabitants), city (20,000 to <100,000 inhabitants), small city (5,000 to <20,000 inhabitants) and rural community (<5,000 inhabitants)), migration background (born in Germany yes vs. no) were collected for descriptive purposes only.

Statistical analysis

Descriptive statistics (mean, standard deviation, 95% confidence interval, absolute and relative frequencies) were calculated for the sample's characteristics, digital media use and PA. Furthermore, multivariable adjusted linear regressions were conducted with total digital media use, the individual media devices and total social media use, respectively, as independent variable and PA as dependent variable. This resulted into 12 different models: 6 models for the period of strict infection control measures and 6 for normal times. As recommended by Evans et al. (2012), theory-based selection of covariates was combined with the change in estimate procedure. The previously selected covariables (further explanation in the supplementary material S1a and S1b) were accounted for the final model if the inclusion of the covariable led to a deviation in the digital media estimate of +/- 10% compared to the unadjusted model (supplementary material S2). Multicollinearity was assessed by the variance inflation factor (VIF; critical if > 2.5) and tolerance (TOL; critical if < 0.25).

For sensitivity analysis, interaction by sex was assessed by including interaction terms (media variable*sex) into the linear models. Stratified analyses were conducted if the interaction term reached a p-value of ≤ 0.1. As a consequence, sex stratified analyses were performed for the following digital media variables: PC/computer/tablet, gaming console and total social media use during the period of strict infection control measures, smartphone, computer/pc/tablet and total social media use during normal times. As a second sensitivity analysis, mean digital media use and PA for the period of strict infection control measures and for normal times were calculated stratified for whether or not the PA guidelines were adhered to. All analyses were conducted on a full case data set regarding independent, outcome and confounder variables and performed with SAS 9.4 (SAS Institute, Cary, NC, USA).

Results

Participants' characteristics

A total of 884 participants were included in the study. Overall, 76.0% were female and the mean age was 22.36 (SD 1.99). The sample was quite homogenous regarding their country of origin (98.0% born in Germany), their education (99.4%. had a high school degree) and their financial situation (33.5% and 40.7% coped financially very well and well, respectively). The majority of participants were recruited via university/college (commonly mailing lists) (86.54%) and only few through acquaintances (8.37%) or social media (2.60%). More detailed information on the sample's characteristics is presented in Table 1.

Table 1. Demographic characteristics of the study population.

Demographic characteristic	N (%)
Number of observations	**884**
Sex	
Female	672 (76.02)
Male	212 (23.98)
Age in years, mean (SD; 95% CI)	22.36 (±1.99; 22.23-22.49)
Born in Germany	
Yes	866 (97.96)
No	16 (1.81)
Missing	2 (0.23)
Community size	
Large metropolis (≥500,000 inhabitants)	57 (6.45)
Small metropolis (100,000 to <500,000 inhabitants)	141 (15.95)
City (20,000 to <100,000 inhabitants)	273 (30.88)
Small city (5,000 to 20,000 inhabitants)	181 (20.48)
Rural community (less than 5,000 inhabitants)	231 (26.13)
Missing	1 (0.11)
High school degree	
Yes	879 (99.43)
No	5 (0.57)
Vocational degree	
No vocational degree	493 (55.77)
College/ university	244 (27.60)
Technical college	12 (1.36)
Vocational training	135 (15.27)
Financial coping	
Very well	296 (33.48)
Well	360 (40.72)
With minor difficulties	155 (17.53)
With difficulties	48 (5.43)
With major difficulties	30 (2.26)
I do not know	5 (0.57)
Access to the questionnaire via	
Social media	23 (2.60)
College/university (e.g. mailing lists)	765 (86.54)
School	17 (1.92)
Acquaintances/friends	74 (8.37)
Another way	5 (0.57)

N number of observations, SD standard deviation, CI confidence interval

Changes in digital and social media use, physical activity and covariates

Compared to normal times, an increase in digital and social media use for all devices surveyed during the period of strict infection control measures could be observed (Table 2), with especially stark increases for total digital media use (mean hours 5.54 (SD 2.29) vs. 7.35 (SD 2.78)). Mean total social media use rose by 1 hour from 2.74 hours (SD 1.69) during normal times to 3.77 hours (SD 2.33) during the period of strict infection control measures. Mean PA (days of ≥ 30 minutes) decreased slightly from 3.76 days/week (SD 1.89) during normal times to 3.65 days/week (SD 2.05) during the period of strict infection control measures. Nonetheless, approximately 60% of participants did not adhere to the PA recommendations regardless of time. Despite minor changes in PA, the proportion of respondents working without any physical exertion (sitting activity without physical exertion) increased from 37.2% to 72.4%.

Although most respondents were students at both time periods, their number decreased from 87.1% to 67.7%, while the else category increased. Whereas there were only little changes in time caring for other people, an increase in free time for more than half of the respondents (53.7%) could be noted.

The relationship between digital media use and physical activity behavior

Overall, there was a negative association between total digital media use and PA behavior during normal times and during time of COVID-19 intervention (β = -0.103, 95% CI [-0.157 - -0.049]; β = -0.082, 95% CI [-0.130 - -0.033], respectively) as well as for total social media use (β = -0.155, 95% CI [-0.229 - -0.082]; β = -0.061, 95% CI [0.120 - -0.003], respectively). Expect for gaming console and PC use, stronger negative associations were observed during normal times. While under normal conditions, the days/week of PA decreased by 0.207 (95% CI [-0.310 – -0.104]) with each additional hour of smartphone use, no significant associations were found for time during COVID-19 intervention. Reversely, negative associations between gaming console and PA were significant during the period of COVID-19 Intervention, but not during normal times (β = -0.207, 95% CI [-0.372 - -0.043]). For TV, negative associations were found for both time periods (Table 3).

Table 2. Distribution of exposures, outcome and covariates during the COVID-19 interventions and during normal times.

Variable		Normal times Mean (SD, 95% CI)	during the COVID-19 interventions Mean (SD, 95% CI)
Media use in hours/day	Smartphone	2.48 (±1.21; 2.40-2.56)	3.00 (±1.31; 2.92-3.09)
	TV	0.83 (±0.95; 0.77-0.89)	1.10 (±1.21; 1.02-1.18)
	PC/computer/tablet	2.04 (±1.39; 1.95-2.14)	2.94 (±1.61; 2.83-3.05)
	Gaming console	0.19 (±0.53; 0.15-0.22)	0.31 (±0.83; 0.25-0.36)
	Total media use	5.54 (±2.29; 5.39-5.69)	7.35 (±2.78; 7.17-7.53)
	Total social media use	2.74 (±1.69; 2.63-2.85)	3.77 (±2.33; 3.62-3.93)
Physical activity ≥30 min. in days/week		3.76 (±1.89; 3.64-3.89)	3.65 (±2.05; 3.52-3.79)
		N (%)	**N (%)**
PA recommendations*	Complied	331 (37.44)	325 (36.76)
	Not complied	553 (62.56)	559 (63.24)
Main occupation	College/university	770 (87.10)	598 (67.65)
	Vocational training/ school/traineeship	40 (4.52)	25 (2.83)
	Employed	36 (4.07)	36 (4.07)
	Unemployed	2 (0.23)	18 (2.04)
	Be on/work short-time	-	10 (1.13)
	Else	36 (4.07)	197 (22.29)
Working hours in main occupation in hours	0	5 (0.57)	18 (2.04)
	1 - <20	133 (15.05)	219 (24.77)
	20 - <30	225 (25.45)	145 (16.40)
	30 - <40	362 (40.95)	241 (27.26)
	≥40	159 (17.99)	261 (29.52)
Physical exertion at main occupation			
	Not working	5 (0.57)	18 (2.04)
	Sitting activity without physical exertion	329 (37.22)	640 (72.40)
	Sitting with some physical exertion	384 (43.44)	137 (15.50)
	Standing or walking activity without physical exertion	86 (9.73)	34 (3.85)
	Standing or walking activity with some physical exertion	50 (5.66)	29 (3.28)
	Manual, physical (very) demanding activity	30 (3.40)	25 (2.83)
	Missing	0	1 (0.11)
Second job	Yes	327 (36.99)	222 (25.11)
	No	557 (63.01)	662 (74.89)
Cohabitation	Living alone	94 (10.63)	81 (9.16)
	Living with others	790 (89.37)	803 (90.84)
Changes in free time	More free time	/	475 (53.73)
	No changes	/	175 (19.80)
	Less free time	/	234 (26.47)
Changes in time caring for others	More time caring	/	128 (14.48)
	No changes	/	288 (32.58)
	Less time caring	/	30 (3.39)
	Does not apply	/	438 (49.55)

N number of observations, SD standard deviation, CI confidence interval, *PA recommendations according to the WHO guidelines: 5 or more days per week of at least 30 minutes of physical activity that raised the breathing rate (WHO, 2010).

Table 3. The relationship between digital media use and physical activity – comparison between normal times and during COVID-19 interventions.

Media use variable	During normal times				During COVID- 19 Intervention			
	Effect estimate	95% Confidence Limits		p-value	Effect estimate	95% Confidence Limits		p-value
Total digital media	-0.103†	-0.157	-0.049	<.0001	-0.082†	-0.130	-0.033	<.0001
Smartphone	-0.207†	-0.310	-0.104	<.0001	-0.104†, ‡, †‡‡	-0.210	0.002	0.0539
TV	-0.299†	-0.429	-0.167	<.0001	-0.147†, †‡	-0.259	-0.035	0.0103
PC	0.019†, ‡, †‡, †‡‡	-0.072	0.110	0.6807	-0.049†, ‡‡, †‡‡, ‡‡‡	-0.135	0.038	0.2692
Gaming console	-0.177†, ‡‡‡	-0.412	0.058	0.1404	-0.207†, ‡, ‡‡	-0.372	-0.043	0.0134
Total social media	-0.155†	-0.229	-0.082	<.0001	-0.061†, ‡	-0.120	-0.003	0.0407

Adjusted for: † Sex; ‡ age; †‡ vocational degree; ‡‡ free time; †‡‡ second job; ‡‡‡ working hours

Table 4. Sex-stratified association between digital media and physical activity behaviour

Digital media variable	Women (N = 672)				Men (N = 212)			
	Effect estimate	95% Confidence Limits		p-value	Effect estimate	95% Confidence Limits		p-value
				During COVID- 19 Intervention				
PC	0.006‡‡, †‡‡, ‡‡‡	-0.093	0.106	0.8989	-0.222‡‡, †‡‡, ‡‡‡	-0.397	-0.048	0.0128
Gaming console	-0.391‡, ‡‡	-0.608	-0.174	0.0004	0.041‡, ‡‡	-0.210	0.292	0.7475
Total social media	-0.032‡	-0.100	0.037	0.3648	-0.141‡	-0.253	-0.030	0.0134
				During normal times				
Smartphone	-0.258	-0.376	-0.140	<.0001	-0.060	-0.272	0.152	0.5797
PC	0.117‡, †‡, †‡‡	0.011	0.223	0.0300	-0.221‡, †‡, †‡‡	-0.402	-0.041	0.0166
Total social media	-0.137	-0.221	-0.054	0.0013	-0.210	-0.364	-0.056	0.0079

Adjusted for: † Sex; ‡ age; †‡ vocational degree; ‡‡ free time; †‡‡ second job; ‡‡‡ working hours

Table 5. Mean digital media use during both periods, stratified according to compliance with PA recommendations

Media use variable	During normal times			During the COVID-19 interventions		
	PA recommendations complied with mean (SD)	PA recommendations not complied with mean (SD)	Difference in means*	PA recommendations complied with mean (SD)	PA recommendations not complied with mean (SD)	Difference in means*
Smartphone	2.27 (±1.18)	2.60 (±1.22)	0.33	2.96 (±1.30)	3.03 (±1.31)	0.06
TV	0.67 (±0.84)	0.93 (±1.0)	0.26	1.03 (±1.12)	1.14 (±1.26)	0.12
PC/computer/tablet	2.08 (1±.41)	2.02 (±1.38)	-0.06	2.90 (±1.63)	2.96 (±1.60)	0.06
Gaming console	0.17 (±0.49)	0.19 (±0.56)	0.02	0.23 (±0.67)	0.35 (±0.91)	0.12
Total media use	5.19 (±2.16)	5.75 (±2.33)	0.55	7.12 (±2.74)	7.48 (±2.79)	0.36
Total social media use	2.46 (±1.51)	2.91 (±1.77)	0.45	3.64 (2.15)	3.85 (±2.43)	0.21

PA physical activity; SD standard deviation. * Difference in means calculated by: mean (PA recommendations not complied with) – mean (PA recommendations complied with).

Interaction analyses indicated interaction by sex in the associations between PC, gaming console and total social media use with PA during the period of strict infection control measures and PC, smartphone and total social media use with PA during normal times, respectively. The subsequent sex-stratified analysis (Table 4) reveals a reverse relationship between the use of PC and gaming console with PA between men and women. While higher PC use was not associated with PA during the period of strict infection control measures and positively associated during normal times in women, it was statistically significant associated with a decrease in PA in men. Among women, the number of days/week of PA decreased by 0.391 (95% CI [-0.608 - -0.174]) for each hour of gaming console use, whereas among men, the number of days per week PA increased (however not significantly) by 0.041 (95% CI [-0.210 - 0.292]). With regard to total social media use, a negative impact on PA was found during the COVID-19 interventions for both women and men. However, it was not statistically significant in women.

The second sensitivity analysis showed that digital media use is generally higher for those not complying with the PA recommendations than those complying with them and it increased for both groups under the period of strict infection control measures. Nevertheless, those complying with the PA recommendations showed a higher increase in digital media use, so that the difference in mean digital media use between both groups is smaller under the period of strict infection control measures than under normal times (Table 5).

Discussion

This study presents data from an online survey comparing the association between digital media use/social media use and PA between the period of strict infection control measures and normal times. Comparable to other studies (Alomari et al., 2020; Colley et al., 2020; Keel et al., 2020; Qin et al., 2020), present results show an increase in digital media use/social media use and in work-related sedentary work during the period of strict infection control measures. However, in contrast to the results of other studies observing a decrease in PA during the pandemic (Alomari et al., 2020; Ammar et al., 2020; Meyer et al., 2020), only small differences in PA were found. This may be due to differences in the extent of infection control measures or seasonal aspects. While in other countries a complete lockdown was implemented (Roser et al., 2020), in Germany the strict infection control measures were less severe and it was allowed to go for a walk or to do individual outdoor sports (RKI, 2020a; RKI, 2020b). This may have resulted into a shift from (organized) sports to more habitual PA (e.g. walking, cycling, gardening, "playing" outside), as it could be observed in German children and adolescents during the times of strict infection control measures (Schmidt et al., 2020). Thus, the overall PA time did not change but the type of PA. Additionally, people engage more often in PA in mild temperatures, such as in spring - as it was during the first wave (Deutscher Wetterdienst, 2020) -, than in cold or very hot seasons (Turrisi et al., 2021). Another reason might be differing methods of measuring PA. Alomari et al. (2020) and Meyer et al. (2020), for instance, asked about the participants' subjective perception of whether they decreased or increased PA. In contrast, Ammar et al. (2020) used the International Physical Activity Questionnaire Short Form (IPAQ-SF). However, regardless of the time period, about 60% of the sample did not comply with PA recommendations which is comparable to previously published European (Wicker and Frick, 2017) and US American data (Singh et al., 2020).

The strength of the associations between digital media use and PA during normal times was similar to other studies (Grimaldi-Puyana et al., 2020; Lepp et al., 2013). Stronger associations were found under normal conditions compared to the period of strict infection control measures, except for game console and PC use. During normal times, the level of digital media use was higher in those not complying with PA recommendations compared to those who complied with the recommendations. Although the level of digital media use increased for both groups during the period of strict infection control measures, the increase was higher for those complying with PA recommendations. As a result, the difference between both groups is less pronounced during the period of strict infection control measures. Considering that more than half of the sample (53.7%) had more free time during the pandemic, it can be assumed that this gain in time is spent rather on digital media use instead of engaging in more PA. Regarding social media use, this study observed a negative association with PA, in contrast to previous studies indicating both a positive and a negative association (Raggatt et al., 2018; Shimoga et al., 2019; Vaterlaus et al., 2015). Whether social media use impacts PA positively or negatively depends primarily on the context of use (Vaterlaus et al., 2015) and the content viewed (Raggatt et al., 2018). Raggatt et al. (2018), for instance, found that while "fitspiration" content may provide access to health information, it can also affect the wellbeing if users fail to reach the promoted ideal and, consequently, putting them at risk of developing eating disorders. In addition, Shimoga et al. (2019) observed that a moderate intensity of social media use, rather than extremely low or high use, has the most beneficial impact on PA. In this study, however, total social media use in general was studied, without differentiating between content of or reasons for using social media. For instance, a positive relationship may have been observed for sports content, whereas for other content the negative associated found in this study may hold true.

Furthermore, the results indicate differences by sex. PC use was negatively associated with PA in men, whereas no association or a positive association was found in women. This may be due to differences in gaming behavior between men and women. Considering adolescents, findings of a multinational study showed that gaming in general is associated negatively with PA in boys whereas non-gaming PC use is weakly positive associated with PA in both genders (Melkevik et al., 2010). The sex differences in the association between PC use and PA found in this study may be explained by the fact that men are more likely to play video games on PC than women (Newzoo, 2017) and that we did not differentiated between gaming and non-gaming PC use. Because of the small number of participants using gaming consoles and since men are underrepresented in this study, results regarding gaming console use should be interpreted with caution. Different associations between men and women were also found for social media use. Here, social media use was more strongly associated with a lack of PA in men. The existing literature suggests that body image may be an explanatory factor for gender differences in social media use (Bassett-Gunter et al., 2017; Ramos-Jimenez et al., 2017; Tiggemann and Zaccardo, 2015). Further research should focus the role of body image in the path from social media use to PA.

Limitations

Naturally, this study has to be interpreted in light of its limitations. Foremost, a cross-sectional study was conducted and, therefore, no assumptions can be made about a causal relationship between digital media use and PA. Additionally, recall bias has to be noted as a possible threat to validity as the data collection took place in summer, asking about behavior last spring. Nonetheless, the level of mean digital media use was comparable to other studies. In accordance with other studies in this field employing an online questionnaire (Alomari et al., 2020; Ammar et al., 2020; Eek et al., 2021; Faulkner et al., 2020; Jia et al., 2020; Meyer et al., 2020; Pišot et al., 2020), women are overrepresented in this study. Recent literature has found sex differences in response rates by survey mode (e.g. mail, online based, telephone survey) (Mulder and de Buijine, 2019), with women, for example, being 1,5 times more likely to respond to mail surveys (Robb et al., 2017). To our knowledge, there is no current research examining sex stratified response rates differentiating between several modes of online recruitment, such as email, social media, smartphone. The overrepresentation of women in our study might be due to differing email response rates between both sexes, as the majority of our sample was recruited through university mailing lists. Since the sample was quite homogenous with respect to high school graduation, migration background and main occupation (students), the results are only partly transferable to young adults with low socioeconomic status or migration background. The difference in the proportion of students between normal times and the period of strict infection control measures is probably explained by the fact that many students finished their studies (the university semesters end generally in March/April in Germany). Furthermore, information on PA during the COVID-19 interventions were referring to spring months (March to May), whereas data on PA during normal times were asked for winter months (before March 2020). As PA is often lower in winter (Turrisi et al., 2021), bias may be introduced through these seasonal aspects. Finally, it is difficult to calculate the response rate for online questionnaire (it cannot be known how many respondents could have been reached) and, thus, to make assumptions about non-responder bias.

Strengths

Nonetheless, this study has also several strengths worth noting. First of all, information on digital media use was collected comprehensively by asking about the use of various devices and separately for weekdays and weekend. Furthermore, PA was measured with a valid and reliable single-item question and, hence, can be compared with other studies. By first building an "association model" based on current literature and then applying the change in estimate procedure for each linear model, we also followed a comprehensive procedure for confounder selection. To assess possible selection bias related to disseminating the questionnaire through social media, participants were asked where they encountered the questionnaire. Answers to this question showed that nearly all participants (86.5%) were recruited via university/college and only 2.6% of all respondents through social media. Consequently, selection bias in respect of including mostly people that would be more likely to have a high screen time and to be physically inactive appears to be unlikely. Above all, this study provides insights in changes in digital media use and PA and its association during the COVID-19 pandemic which, for the latter, not have been reported for European young adults yet.

Conclusion

This study confirms initial assumptions about changes in media use and PA during the COVID-19 pandemic in Germany. Due to changing conditions and infection control measures over time, longitudinal studies are needed to confirm associations and examine effects on long-term behaviors. Although no major decrease in PA was observed, about 60% of all respondents did not comply with PA recommendations. Therefore, interventions are needed to increase PA in general and prevent decreases in PA over the course of the pandemic. Initial approaches of online exercise programs show already positive results (Looyestyn et al., 2018). Social media seems to have a major impact on young adult behavior and could, therefore, used as the medium for promotion and interventions of PA.

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Key points

- Digital media and social media use increased each by one hour during the time of COVID-19 intervention of the first wave compared to normal times before the pandemic.
- Little changes in physical activity during the pandemic's first wave.
- Negative association between digital media/social media use and physical activity was observed.
- There are differences in this association between men and women for some digital media devices.

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SUPPLEMENTARY MATERIALS

Supplemental material S1.

S1a. The "association model"

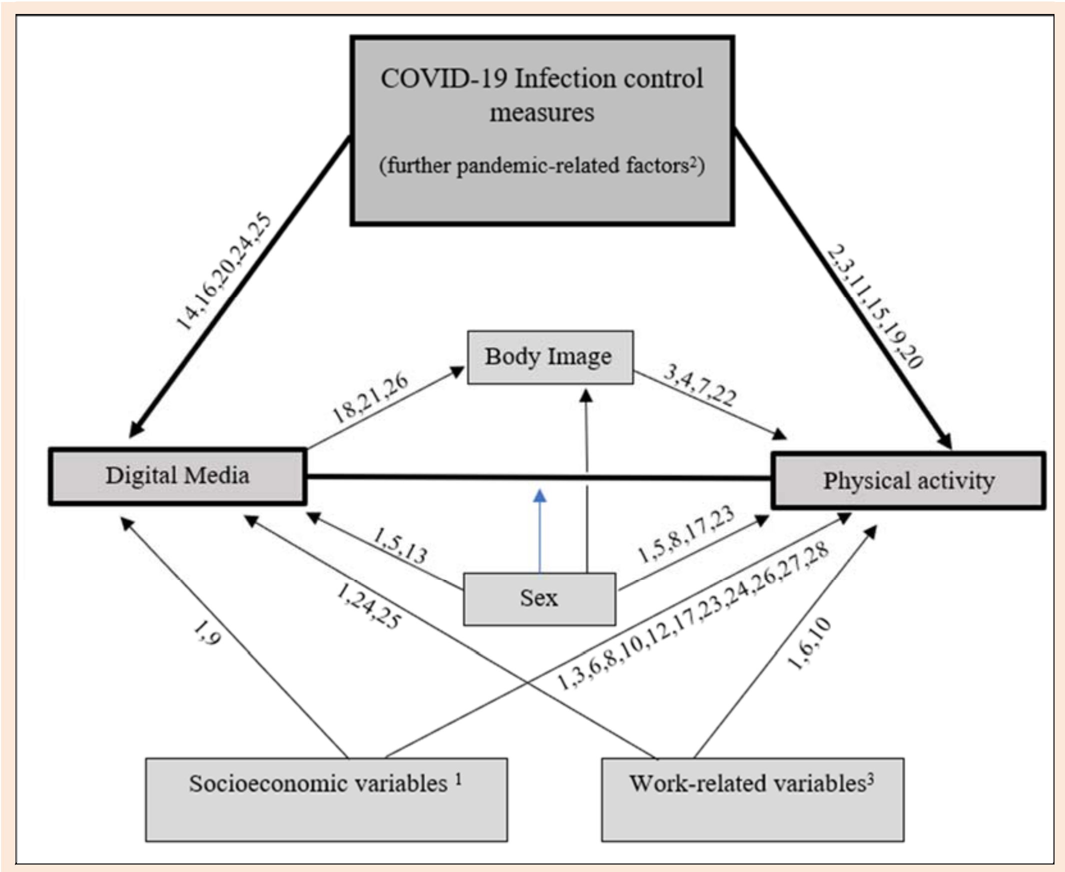

Figure 1. The "association model". [1] high school degree, vocational degree, financial coping, age, cohabitation, [2] free time, for other persons, [3] main occupation, second job.

Reference numbers: 1 (Alomari et al., 2020), **2 (**Ammar et al., 2020), **3** (Asthon et al., 2017), **4** (Basset-Gunter et al., 2017), **5 (**Cook etal., 2018), **6 (**Diehl etal., 2018), **8** (Faulkner etal., 2020), **9** (Hruska and Maresova, 2020), **10 (**Isoard-Gautheur et al., 2019**), 11** (Jia et al., 2020), **12** (Kantomaa et al., 2016), **13** (Keel et al., 2020), **14** (Lucini et al., 2020), **15** (McDowell et al., 2020), **16** (Meyer et al., 2020), **17** (Miller et al., 2018), **18** (Miranda et al.., 2018), **19** (Ong et al., 2020), **20** (Pišot et al., 2020), **21** (Radwan et al., 2018), **22** (Ramos-Jimenez et al., 2017), **23** (Rapp et al., 2013), **24** (Smith et al., 2014), **25** (Sturm and Cıhen, 2019), **26** (Tiggemann and Zaccardo, 2015), **27** (VanKim and Laska, 2012), **28** (Werneck et al., 2020).

S1b. Methodological procedure

As a first step in the model building strategy, possible covariates were identified based on current literature. Instead of building a directed acyclic graph (DAG) as recommended by Evans et al. (2012), we designed an "association model" (Figure 1) without adhering to the strict building rules of a DAG. This decision was due to the cross-sectional design of our study which deters from drawing conclusions about causality. Thus, the model shows rather the association of digital media use and physical activity without indication of causality. As a second step, the change in estimate procedure was used to decide on the final confounder set for each model and is further explained in S2.

To decide which variables we need to include as confounder in this "association model" (Supplemental material S1), we applied the common rules for confounder: 1) the confounder must be a cause (or its surrogate) for the outcome, 2) the confounder has to be associated with the exposure and 3) it must not be an intermediate step between the exposure and the outcome (McNamee, 2003). We also looked at the additional (stricter) rule proposed by McNamee (2003) 3a) the confounder must not affect the exposure. In doing so the following variables were selected as possible confounder (and later tested in the change in estimate procedure): work-related variables (main occupation, working hours and second job), sex, further socio-demographic variables (school leaving degree, vocational degree, financial coping, age and cohabitation) and pandemic-related variables (changes in free time and caring time for other people). The COVID-19 interventions were not included in the set of possible confounders as the linear regression models were performed for the period of COVID-19 interventions and normal times separately. As the arrows' direction indicate, body image could be determined as an intermediate factor in the relation of digital media use, foremost social media use (Bassett-Gunter et al., 2017; Miranda et al., 2018; Ramos-Jimenez et al., 2017; Tiggemann and Zaccardo, 2015), and physical activity. Thus, it does not fulfill the third confounder rule and was not accounted for in the main regression models. However, an exploratory mediation analysis was conducted to estimate the proportion of the total effect of social media use on physical activity mediated by body image (detailed explanation of the procedure in S3; the mediation analysis is not reported in the main manuscript owing to methodological weaknesses explained in S3). In addition, the blue arrow indicate that sex can act an effect modifier and, therefore, further analyses tested for an interaction of digital media use and sex. The variables community size and physical exertion at main occupation were not suited as possible confounder since they did not fulfill the second confounder rule. In addition, the variable migration background was not considered in this "association model" as the sample is homogenous in this respect. Therefore, these variables are only used for the description of the sample.

Supplemental material S2. The change in estimate procedure

After identification of possible confounders by literature search and building the theory-based "association model" explained in S1, the change in estimate procedure was used to determine the final set of confounders for each linear model. As commonly used in current research (Evans et al., 2012), a cut-off value of +/- 10% deviation of the adjusted estimate compared to the unadjusted estimate of digital media use was set. Apart from sex as a forced in variable, differing sets of confounders were obtained for each model. Despite examining the same independent digital media variable, the models of the period of the COVID-19 interventions or normal times, respectively, were adjusted for different set of confounders. This is because different covariables can act as confounders in different situations (e.g. change in free time owing to the COVID-19 interventions or change in working conditions). Table 6 shows the change in estimate (in %) for all possible confounders for each model and the decision whether or not to include the confounder in the final set of confounders.

Table 6. Calculation of the change in estimate (CIE).

Exposure	Covariate	During normal times			During the COVID-19 interventions		
Media use variable		**Estimate**	**CIE**	**CIE %***	**Estimate**	**CIE**	**CIE %***
Total media	-†	-0,1031			-0,0794		
	Caring time	/			-0,0769	-0,03	-3,21%
	Free time	/			-0,0749	-0,06	-5,71%
	Age	-0,1039	0,01	0,77%	-0,0781	-0,02	-1,68%
	Sex	-0,1027	0,00	-0,39%	-0,0818	0,03	3,06%
	Cohabitation	-0,1034	0,00	0,23%	-0,0790	-0,01	-0,57%
	Main occupation	-0,1021	-0,01	-1,03%	-0,0769	-0,03	-3,19%
	Working hours	-0,0942	-0,09	-8,61%	-0,0801	0,01	0,92%
	Second job	-0,1058	0,03	2,60%	-0,0753	-0,05	-5,20%
	High school degree	-0,1026	0,00	-0,48%	-0,0796	0,00	0,24%
	Vocational degree	-0,1047	0,02	1,51%	-0,0786	-0,01	-1,07%
	Financial coping	-0,1036	0,00	0,44%	-0,0818	0,03	3,06%
Smartphone	-†	-0,2075			-0,1132		
	Caring time	/			-0,1085	-0,04	-4,12%
	Free time	/			-0,1142	0,01	0,87%
	Age	-0,2034	-0,02	-2,00%	-0,0968	-0,14	-14,46%‡
	Sex	-0,2066	0,00	-0,44%	-0,1308	0,16	15,58%‡
	Cohabitation	-0,2063	-0,01	-0,61%	-0,1134	0,00	0,20%
	Main occupation	-0,2047	-0,01	-1,34%	-0,1107	-0,02	-2,16%
	Working hours	-0,1938	-0,07	-6,60%	-0,1090	-0,04	-3,69%
	Second job	-0,2020	-0,03	-2,66%	-0,0979	-0,14	-13,54%‡
	High school degree	-0,2070	0,00	-0,26%	-0,1109	-0,02	-2,00%
	Vocational degree	-0,2027	-0,02	-2,30%	-0,1036	-0,09	-8,51%
	Financial coping	-0,2087	0,01	0,58%	-0,1199	0,06	5,96%
TV	-†	-0,2997			-0,1113		
	Caring time	/			-0,1077	-0,03	-3,23%
	Free time	/			-0,1226	0,10	10,10%
	Age	-0,2999	0,00	0,07%	-0,1139	0,02	2,32%
	Sex	-0,2981	-0,01	-0,53%	-0,1202	0,08	7,99%
	Cohabitation	-0,3000	0,00	0,08%	-0,1114	0,00	0,08%
	Main occupation	-0,2995	0,00	-0,09%	-0,1046	-0,06	-6,06%
	Working hours	-0,2800	-0,07	-6,57%	-0,1084	-0,03	-2,68%
	Second job	-0,2963	-0,01	-1,14%	-0,1007	-0,10	-9,59%
	High school degree	-0,3006	0,00	0,29%	-0,1110	0,00	-0,29%
	Vocational degree	-0,3012	0,00	0,50%	-0,1260	0,13	13,16%‡
	Financial coping	-0,2997	0,00	0,00%	-0,1132	0,02	1,67%

* Change in estimate in percent calculated by: $\frac{\text{adjusted media use estimate} - \text{crude media use estimate}}{\text{crude media use estimate}} * 100$ † crude estimate (not adjusted for any covariate). ‡ included as confounder in the respective model

Table 6. **Continued..**

Exposure	Covariate	During normal times			During the COVID-19 interventions		
Media use variable		Estimate	CIE	CIE %*	Estimate	CIE	CIE %*
PC/computer/tablet	-†	0,0469			-0,0465		
	Caring time	/			-0,0465	0,00	0,06%
	Free time	/			-0,0205	-0,56	-55,94%‡
	Age	0,0408	-0,13	-13,10%‡	-0,0499	0,07	7,38%
	Sex	0,0445	-0,05	-5,18%	-0,0461	-0,01	-0,88%
	Cohabitation	0,0451	-0,04	-3,92%	-0,0457	-0,02	-1,74%
	Main occupation	0,0491	0,05	4,62%	-0,0473	0,02	1,70%
	Working hours	0,0467	0,00	-0,43%	-0,0564	0,21	21,39%‡
	Second job	0,0323	-0,31	-31,15%‡	-0,0570	0,23	22,69%‡
	High school degree	0,0483	0,03	2,83%	-0,0507	0,09	9,21%
	Vocational degree	0,0358	-0,24	-23,76%‡	-0,0422	-0,09	-9,15%
	Financial coping	0,0469	0,00	-0,04%	-0,0468	0,01	0,67%
Gaming console	-†	-0,1911			-0,1899		
	Caring time	/			-0,1833	-0,03	-3,48%
	Free time	/			-0,2121	0,12	11,70%‡
	Age	-0,1976	0,03	3,39%	-0,2093	0,10	10,23%‡
	Sex	-0,2134	0,12	11,66%‡	-0,1735	-0,09	-8,64%
	Cohabitation	-0,1890	-0,01	-1,12%	-0,1926	0,01	1,42%
	Main occupation	-0,1917	0,00	0,31%	-0,1793	-0,06	-5,59%
	Working hours	-0,1599	-0,16	-16,37%‡	-0,1878	-0,01	-1,10%
	Second job	-0,1770	-0,07	-7,38%	-0,1737	-0,09	-8,50%
	High school degree	-0,1901	-0,01	-0,57%	-0,1881	-0,01	-0,92%
	Vocational degree	-0,1722	-0,10	-9,90%	-0,2004	0,06	5,53%
	Financial coping	-0,1916	0,00	0,25%	-0,1966	0,04	3,54%
Total social media	-†	-0,1561			-0,0659		
	Caring time	/			-0,0640	-0,03	-2,85%
	Free time	/			-0,0626	-0,05	-5,02%
	Age	-0,1534	-0,02	-1,77%	-0,0572	-0,13	-13,14%‡
	Sex	-0,1551	-0,01	-0,69%	-0,0698	0,06	5,95%
	Cohabitation	-0,1561	0,00	-0,03%	-0,0652	-0,01	-1,03%
	Main occupation	-0,1588	0,02	1,73%	-0,0680	0,03	3,14%
	Working hours	-0,1542	-0,01	-1,26%	-0,0658	0,00	-0,15%
	Second job	-0,1579	0,01	1,13%	-0,0605	-0,08	-8,15%
	High school degree	-0,1571	0,01	0,58%	-0,0651	-0,01	-1,20%
	Vocational degree	-0,1504	-0,04	-3,69%	-0,0623	-0,06	-5,51%
	Financial coping	-0,1584	0,01	1,42%	-0,0724	0,10	9,91%

* Change in estimate in percent calculated by: $\frac{\text{adjusted media use estimate} - \text{crude media use estimate}}{\text{crude media use estimate}} * 100$ † crude estimate (not adjusted for any covariate). ‡ included as confounder in the respective model