The impact of coronavirus (COVID-19) related public-health measures on training behaviours of individuals previously participating in resistance training: A cross-sectional survey study

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ABSTRACT

Introduction: Understanding the impact of lockdown upon RT, and how people adapted their RT behaviours, is expected to have implications for strategies to maintain engagement in positive health behaviours such as this during- restrictive pandemic-related public health measures. Further, doing so will provide a baseline for investigation of the long-term effects of these measures upon behaviours and perceptions and facilitate future follow-up study.
Objectives: To determine how the onset of coronavirus (COVID-19), and the associated 'lockdown', affected resistance training (RT) behaviours, in addition to motivation, perceived

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effectiveness, enjoyment, and intent to continue, in those who regularly performed resistance training RT prior to the pandemic. **Methods:** We conducted an observational, cross-sectional study using online surveys in multiple languages (English, Danish, French, German, Italian, Portuguese, Slovakian, Swedish, and Japanese) distributed across social media platforms and through authors professional and personal networks. Adults (*n* = 5389 after data cleaning; median age = 31 years [interquartile range (IQR) = 25, 38]), who were previously engaged in RT prior to lockdown (median prior RT experience = 7 years [IQR = 4, 12]) participated. Outcomes were self-reported RT behaviours including: continuation of RT during lockdown, location of RT, purchase of specific equipment for RT, method of training (e.g. alone, supervision etc.), full-body or split routine, types of training, repetition ranges, exercise number, set volumes (per exercise and muscle group), weekly frequency of training, perception of effort, whether training was planned/recorded, time of day, and training goals. Secondary outcomes included motivation, perceived effectiveness, enjoyment, and intent to continue RT. **Results:** A majority of individuals (82.8%) maintained participation in some form of RT during- lockdown. Marginal probabilities from generalised linear models and generalised estimating equations of engaging in certain RT behaviours were largely similar from pre- to during- lockdown (particularly numbers of exercises, sets per exercise or muscle group, and weekly frequencies). There was reduced probability of training in privately owned gyms (~59% to ~7%) and increased probability of training at home (~18% to ~89%); greater probability of training using a full-body routine (~38% to ~51%); reduced probability of resistance machines (~66% to ~13%) and free weight use (~96% to ~81%), and increased probability of bodyweight training (~62% to ~82%); reduced probability of moderate repetition ranges (~62-82% to ~55-66%) and greater probability of higher repetition ranges (~27% to ~49%); and moderate reduction in the perception of effort experienced during- training (*r* = 0.31). Further, individuals were slightly less likely to plan or record training during- lockdown and many changed their training goals as a result of lockdown. Additionally, perceived effectiveness, enjoyment, and likelihood of continuing current training were all lower during- lockdown. **Conclusions:** Those engaged in RT prior to lockdown appeared mostly able to maintain these behaviours with only slight adaptations in both the location and types of training performed. However, people employed less effort, had lower motivation, and perceived training as less effective and enjoyable, reporting that their likelihood of continuing current training was similar or lower than pre-lockdown. These results have implications for strategies to maintain engagement in positive health behaviours such as RT during- restrictive pandemic-related public health measures. **Pre-registration:** https://osf.io/qcmpf

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1.0 Introduction

Resistance training (RT) is a well-established method of exercise for promoting health- and fitness-related benefits [1]. Muscle-strengthening through regular practice of RT is universally recognized as an important component of public health guidelines to promote health and some have called for a greater emphasis on RT specifically in their recommendations [2]. Current physical activity guidelines recommend that adults partake in at least two sessions per week of 'muscle strengthening activity', such as RT, for the major muscle groups of the body [3-5]. Recent estimates from self-report data indicate that ~20% to 30% meet recommendations for engaging in 'muscle strengthening activities' [6,7]. When RT specifically is considered as the activity, these estimates appear considerably lower [8-12].

Though engagement in efficacious RT is possible in a range of settings and with a variety of modalities [2], commercial gyms and leisure facilities are a popular option for those seeking to carry out RT programs. These facilities offer a wide range of equipment and amenities not available to most in a home-based setting, thus facilitating engagement. Moreover, the gym environment can foster a sense of camaraderie and motivation, which in turn may positively influence exercise adherence [13]. For example, a study of over 400 adults found that health club members were 10 times more likely compared to non-members to meet or exceed muscle-strengthening guidelines [14].

In early 2020, the onset of the coronavirus (COVID-19) global pandemic and consequent 'social distancing' measures resulted in the temporary, and in some cases extended, global closure of many gyms and leisure facilities (amongst other services and amenities as part of wider measures); colloquially referred to as 'lockdown'. As such, millions of gym members were forced to change their exercise habits. Research as to how COVID-19-associated restrictions influenced general physical activity levels is somewhat equivocal, with some studies indicating an increase in overall participation [15-17] and others showing a negative impact [18,19]. Variances appear to be explained, at least in part, by region-specific and both demographic and socio-economic factors [19,20]. However, while these studies provide insights into general global physical activity patterns, there is little research into how the pandemic influenced RT behaviours which are typically performed in gym settings. While one report suggested that women and younger ages groups may have reduced engagement in RT [20], others have reported RT as being a more common form of exercise during the lockdown [18]. With the closure of the typical locations for engaging in RT, many have offered recommendations to adapt and continue engagement in 'muscle strengthening activity' such as RT at home, and with

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alternative modalities (such as bodyweight exercise or home equipment), both for the general population [21-25], and for sports participants [26-28].

Understanding the impact of lockdown upon RT, and how people adapted their RT behaviours, is expected to have implications for strategies to maintain engagement in positive health behaviours such as this during- restrictive pandemic-related public health measures. Further, doing so will provide a baseline for investigation of the long-term effects of these measures upon behaviours and perceptions and facilitate future follow-up study. Therefore, the purpose of this study was to determine how the onset of COVID-19, and the associated lockdown, affected RT behaviours, in addition to motivation, perceived effectiveness, enjoyment and intent to continue, in those who regularly performed RT prior to the pandemic.

2.0 Methods

Please note, all supplementary materials referred to throughout this pre-print are labelled from S1-S25 and are available in the supplementary files folder on the Open Science Framework project page (see, https://osf.io/xhryf/).

2.1 Study Design

An online cross-sectional survey study was conducted during- April and May 2020 during- which time a number of governments worldwide had implemented lockdown strategies in an effort to contain the spread of COVID-19. The initial phase of this overall project, which also includes qualitative data capture (currently ongoing) and longitudinal follow-up scheduled to be conducted in April and May 2021, sought to examine the immediate impact of lockdown upon the RT behaviours of those who were regularly engaged in such behaviours prior to lockdown. Intention to conduct this study was pre-registered on the Open Science Framework (https://osf.io/qcmpf). Where deviations from the originally pre-registered protocol occurred, these are detailed in this manuscript. This study received ethical approval from the Health, Exercise, and Sport Science Ethics Committee at Solent University (fishj2020).

2.2 Sampling and Population

Surveys were conducted in two stages: first, an English language survey was launched on April 23rd 2020; this was then followed up by the launch of translated versions of the survey (Danish, French, German, Italian, Portuguese, Slovakian, Swedish, and Japanese) on April 29th and 30th 2020. All surveys remained open until May 15th 2020. The survey was primarily distributed

via hyperlink across social media platforms and through a number of the authors' professional and personal networks.

Our original target sample size was n = 2606 based upon two considerations that are detailed in the pre-registration: 1) that required for detection of a 'small' effect size at a power of $\beta = 0.80$, and an adjusted $\alpha = 0.004$ for the number of dependent variables originally pre-registered[1] (14 questions relating to RT behaviours); and 2) based on this yielding an acceptable precision of estimate for survey responses of 2% margin of error at the 95% confidence level, based upon estimated worldwide participation rates for RT.

Across the nine surveys a total of 18,862 respondents accessed the open links to the survey, with 7,947 completing all required questions. Participants were provided with an information sheet containing all details of the study, and then were required to confirm they had understood this and provide informed consent to participate. We implemented a number of screening criteria to yield a final data set to be included in analysis. Those who did not meet the inclusion criteria (self-reported as previously engaged in RT ~2x/week in line with current physical activity guidelines [3-5] for at least six months prior to lockdown, and if their usual training facility was currently inaccessible AND/OR they were engaging in social distancing due to government recommended/implemented measures[2]) were excluded, as were those failing the attention check included in the survey or any responses to the question designed to screen for bots. We also removed participants with out of range responses[3] for any continuous open field variables in the survey[4]. The final sample size included in the analysis was n = 5389.

[1] Notably, our original analysis approach was incorrect as some aspects of the measures used were overlooked in the haste with which the project was set-up and launched in response to the implementation of lockdown measures. We detail these changes below, though due to the final sample size yielded we are confident that, under the assumptions of the data generating process and model used, our results offer sufficient power for any tests, and a high degree of precision for interval estimates.

[2] Due to the known variation in both timing of the pandemic's effects, and the implementation of containment measures, across different countries we screened prior to inclusion such that only individuals who were currently impacted by these measures were included. Based upon survey timings respondents had therefore been under lockdown conditions including closures of their usual training facility AND/OR social distancing for ~3-5 weeks.

[3] The limits set can be seen in the analysis code available in supplementary file (S1).

[4] An exception to this was for income. We asked respondents to provide their annual household incomes in the currency appropriate based on their country of residence, followed by selecting from a list of currency codes the one used. We then used currency exchange rates (as of 31st July 2020) to convert all values to EUR. However, this yielded a high proportion of very high values (860 respondents with annual household incomes above 1 million EUR) leading us to question whether these questions had been understood fully. Thus, we chose not to filter by this variable due to concerns regarding the quality of this data. We plan to attempt to address this during- follow up and obtain data that might be used for retrospective examination of income effects.

2.3 Survey Implementation and Measures

The surveys were administered through JISC Online Surveys (Bristol, UK). All surveys are available in the files in the supplementary files (S2). Further, we have setup a dummy version of the online survey so that readers can access it to see exactly how questions were presented to respondents (https://solent.onlinesurveys.ac.uk/covid-19_rt_survey_copy). In brief, the survey was designed to take no longer than ~10 minutes to complete and asked participants to provide general demographic and personal details, followed by 15[5] questions relating to different aspects of their RT behaviours prior to implementation of lockdown measures. These included questions regarding:

1. Where participants undertook resistance training.
2. Whether they purchased specific equipment for resistance training.
3. How they trained i.e., alone, with a partner, supervised etc.
4. Whether they performed full body or split routines.
5. The types of training they performed.
6. The repetition ranges used.
7. Number of exercises per workout.
8. The set volumes per exercise.
9. The set volume per muscle group.
10. The frequency per week they trained.
11. The rating of perception of effort.
12. The current goals for training.
13. Whether they planned their workouts.
14. Whether they recorded their workouts.
15. The time of day they trained.

Participants were then asked if they were currently engaging in RT in addition to their current motivation to train. Those who were still engaged in RT were then prompted to complete the same 15 questions relating to RT behaviours, in addition to questions comparing their current training to their training prior to lockdown regarding its perceived effectiveness, enjoyment, and the likelihood they would continue with their current training program. Participants were also offered the opportunity to complete an open field to provide additional

[5] Note, the pre-registration reported that 14 questions were to be included. However, prior to launch yet after pre-registration, we added an additional question.

information regarding their answers, and were invited to be contacted to participate in both follow-up surveys as well as semi-structured interviews. The questions relating to RT behaviours were a combination of single item response category variables (SRCVs; e.g. yes/no questions), multiple response category response variables (MRCVs; i.e. please select all that apply[6]), and one ordinal variable provided on an 11 point (0-10 point) scale (this was for perception of effort during- RT and the scale used was adapted from one previously developed by Steele et al. [29] available at: https://osf.io/ufvy8/). All survey questions were compulsory and so complete data were available for all those who finished the survey.

2.4 Statistical Analysis

2.4.1 Main Analysis,

The main analysis examined the effects of lockdown upon respondents' self-reported RT behaviours[7]. For all outcomes, those who reported having stopped participating in RT had their responses coded as NAs (in essence dropped i.e., not applicable) for the during- lockdown answers. Thus, we report the proportion of those who reported having stopped participation, and then the main analysis is constrained to examining the change in specific RT behaviours from pre- to during-lockdown.

SRCVs were examined using binomial logistic regression upon response (0 = No, 1 = Yes) examining the within-respondent fixed effect of 'time' (i.e., pre- and during- lockdown; time = 1, and time = 2 respectively). MRCVs responses (0 = No, 1 = Yes) were similarly examined with the within-respondent fixed effect of 'time' (i.e. pre- and during- lockdown; time = 1, and time = 2 respectively), yet with the addition of 'item' as a fixed factor, and the interaction of 'item x time' allowing us to examine how responses to items changed over time. For MRCVs a

[6] We opted to use MRCVs for RT variables to allow for individuals who might vary their routines from week to week (i.e. they may engage in what is referred to as 'periodization') to respond without feeling the need to arbitrarily select a particular category.

[7] As noted, the analysis presented here differs from that which was pre-registered. Due to the haste of project set-up in light of the suddenness of implementation of lockdown measures we overlooked some aspects of the data that would be generated. This included the paired nature of comparisons for SRCVs, and assumptions of dependency between items underlying the MRCVs. Thus, we have ignored our simple original pre-registered analysis plan aimed at testing the hypothesis of marginal independence. Instead, in part due to the sample size achieved which we anticipated would have yielded low *p* values with relative lack of information regarding the meaningfulness of the findings, we have analysed and presented our data using an alternative modelling strategy. We have also opted to avoid dichotomizing the existence of an effect for the main results and therefore did not employ traditional null hypothesis significance testing, which has been extensively critiqued [30,31]. Instead, we consider the implications of all results compatible with these data, from the lower limit to the upper limit of the interval estimates, with the greatest interpretive emphasis placed on the point estimate.

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generalised estimating equations (GEE) approach was used as suggested by Suesse and Liu [32] for analysis of repeated MRCVs; however, we were able to apply unstructured covariance specification to the model, due to the size of our sample, thus yielding the best model fit. In essence, this GEE approach meant we did not make any assumptions about subject-specific joint distributions. Instead, it permitted identification of correlation structures over both time and between items within each MRCV. Unique Respondent Number (URN; i.e. 'case') was specified as the cluster. From these models we extracted and present the predicted marginal probabilities of a positive response (i.e. 1 = Yes) for a given SRCV or item within a MRCV along with their model specific 95% compatibility (confidence) intervals. This was chosen over the presentation of model coefficients as log-odds or odds ratios given that most people find these unintuitive to interpret with many mistaking the latter for probability or risk anyway. These probabilities were then qualitatively interpreted and described. Supplementary model summary tables are available in the supplementary files (S3) including all predictors log-odds estimates, 95% compatibility (confidence) intervals, and *p* values (note, for MRCVs the reference category for 'item' is always the first item on the question based on how it was presented to respondents).

The lone ordinal variable (rating of perceived effort) was analysed comparing pre- and during- lockdown using an asymptotic Wilcoxon test from which a standardised effect estimate was produced. Cohen's *r* was calculated as $\sqrt{\frac{Z}{n}}$ to examine the magnitude of the standardised effect; however, data are also visually presented with an individual paired response plot and accompanying box and whisker in the raw scale units.

All analyses were conducted using R (version 3.6.1; R Core Team, 2019) and RStudio (version 1.2.1335; RStudio Team, 2018). GEE models were produced using the package 'geepack' [33], interaction plots for MRCVs were produced using the package 'sjplot', and all other data visualisation was produced using 'ggplot'.

2.4.2 Exploratory analyses

Analyses performed in an exploratory manner were conducted through visualisation of the dataset. We highlight only those exploratory findings that appear noteworthy in this manuscript.

Firstly, we explored the relationships between demographic characteristics with RT behaviours over time, in addition to whether respondents continued training (for continuation of training we also examined current motivation as a predictor), by examining the naïve probabilities of engaging in RT behaviours over these predictors. For continuous demographic predictors we plotted smoothed conditional means using loess in 'ggplot' and for categorical

demographic predictors we plot means with compatibility (confidence) intervals produced using basic nonparametric bootstrap sampling from the 'Hmisc' package.

Secondly, we explored the impact of RT behaviours engaged in during- lockdown upon perceived effectiveness of training, enjoyment from training, and likelihood of continuing training. For SRCVs and MRCVs we present ridgeplots using 'ggridges' showing the distributions of perceived effectiveness of training, enjoyment from training, and likelihood of continuing training across each of the question items as predictors. For the lone ordinal variable (rating of perceived effort) we plotted smoothed conditional means using loess

3.0 Results

The final number of respondents after filtering for each survey is provided in table 1 in addition to the percentage of the total respondents. Full details of this process, numbers at each stage of the survey, and a separate table of respondents countries are available in the supplementary materials (S4).

Table 1. Responses to surveys

Survey Language	**Total Responses**	**Percentage of Total Responses**
Danish	97	2%
English	3589	67%
French	37	1%
German	196	4%
Italian	639	12%
Japanese	133	2%
Portuguese	421	8%
Slovakian	64	1%
Swedish	213	4%
Total	**5389**	**100**%

Table 2. Descriptive demographics of final sample	
Characteristic	**N = 5389**[1]
Age (years)	31 (25, 38)
Sex	
Female	2023 (38%)
Male	3366 (62%)
Gender	
Man	3366 (62%)
Woman	2023 (38%)
BMI	24.9 (22.8, 27.4)
Race	
Asian	316 (5.9%)
Black	78 (1.4%)
Mixed	277 (5.1%)
Other	135 (2.5%)
Prefer not to disclose	36 (0.7%)
White	4547 (84%)
Development	
Other	14 (0.3%)
Rural	574 (11%)
Suburban	2076 (39%)

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Table 2. Descriptive demographics of final sample	
Characteristic	**N = 5389**[1]
Urban	2725 (51%)
Employment	
Employed full time	2529 (47%)
Employed part time	530 (9.8%)
Furloughed	358 (6.6%)
Other	600 (11%)
Self-employed	891 (17%)
Unemployed	481 (8.9%)
Working Environment	
No	792 (15%)
Yes, but I am still able to work from my usual location	1021 (19%)
Yes, I am currently not working due to being furloughed by my employer, or due to a reduction in freelance work if self employed	1245 (23%)
Yes, I am now working remotely (I was previously based at a non-home location all or most of the time)	2331 (43%)
Had to self-isolate	1133 (21%)
Has children	1181 (22%)
Number of children	
0	2 (0.2%)
1	527 (45%)

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Table 2. Descriptive demographics of final sample	
Characteristic	**N = 5389**[1]
2	487 (41%)
3	129 (11%)
4	30 (2.5%)
5	4 (0.3%)
6	2 (0.2%)
Unknown	4208
Care giver	228 (4.2%)
Educated to university level in related field	1938 (36%)
Resistance training experience (years)	7 (4, 12)
Participated in strength sports	1010 (19%)
Participated in bodybuilding	449 (8.3%)
Participated in endurance sports	1666 (31%)
Participated in other sports	2631 (49%)

[1] Statistics presented: median (IQR); n (%)

3.2 Main Results – Effects of Lockdown on RT Behaviours

As noted, model specific summary tables are available in the supplementary files. Here we focus on reporting the key findings. As intended, and due to the high precision of estimates

for predicted marginal probabilities[8] from the models (see figures below[9]) we emphasise the point estimates and their magnitude in our reporting.

3.2.1 Are you currently engaged in RT?

Of the complete sample of 5389 respondents, 4466 (82.8%) reported to still be engaging in some form of RT during- lockdown.

3.2.2 Where did you usually undertake RT?

The GEE results of this MRCV question are presented in Figure 1. As can be seen clearly, prior to lockdown the greatest probability by a large margin was for individuals to be training in a 'privately owned gym' (~59% probability) with roughly similar probabilities given to all other options comparatively speaking (all ~20% or lower). However, during- lockdown there was a considerable increase in the probability of training at 'home' (~89% probability), and also a slight increase in the probability of training in a 'public park' (from ~8% to 15%). With the exception of 'other' all remaining options dropped to <5% probability, though there was a slightly elevated probability of training in a 'privately owned gym' still at during- lockdown (~7% probability); perhaps influenced by those who were gym owners themselves?

[8] The predicted probabilities can be easily interpreted by considering an example population of $n = 100$. If the probability of some behavior or event is 0.75 (or 75%) for example then this would mean that 75 out of 100 individuals would be engaging in the behavior or experience the event. This may aid readers in interpreting the probabilities presented.

[9] All figures include corresponding 95% compatibility (confidence) intervals for estimates from the models yet in some figures they are so precise that they appear subsumed in the point estimate on the display.

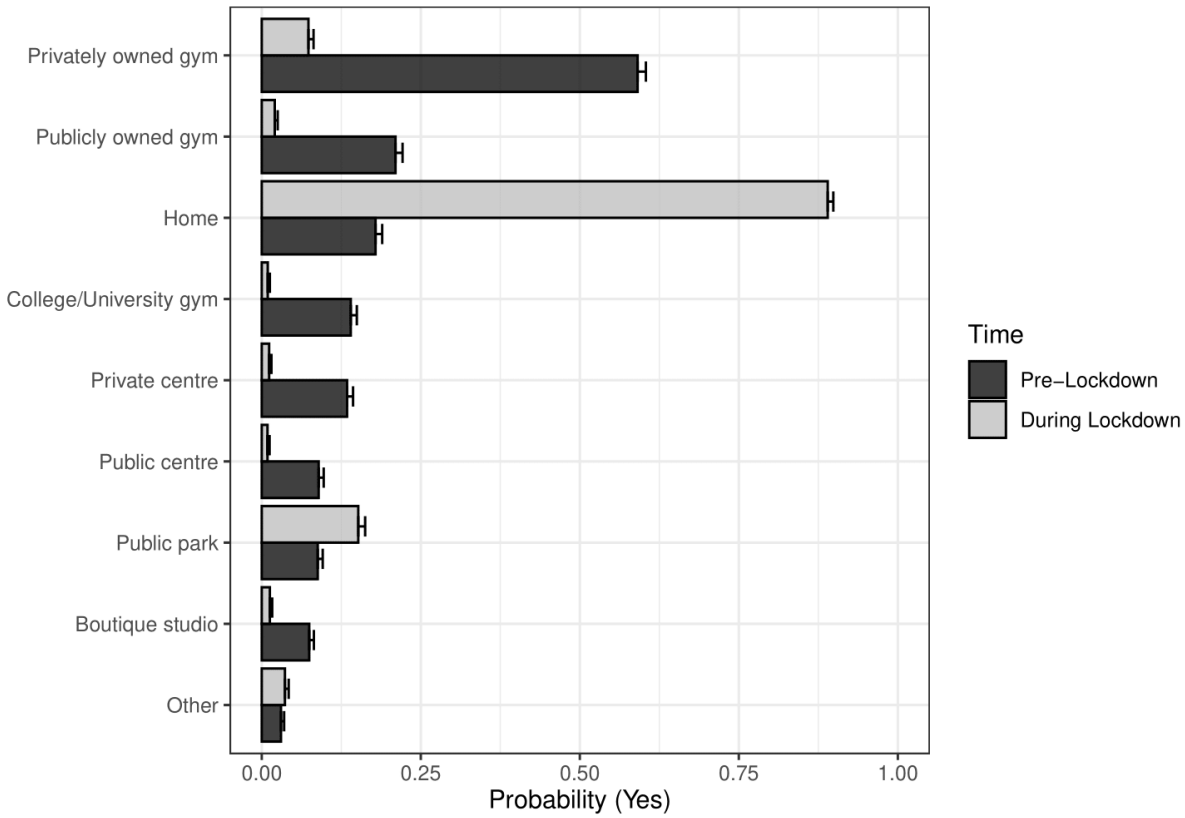

Figure 1. Predicted marginal probabilities for "*Where did you usually undertake RT?*" over 'time' (i.e. pre- and during- lockdown; time = 1, and time = 2 respectively) and 'items'. Note: error bars are 95% compatibility (confidence) intervals; y axis is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.2.3 Have you previously purchased specific equipment (including weights, machines, bands, or other devices) to support your RT?

The binomial logistic regression results of this SRCV question are presented in Figure 2. Individuals were more likely to have purchased specific equipment prior to lockdown (~70% probability) as compared to during- lockdown (~48% probability).

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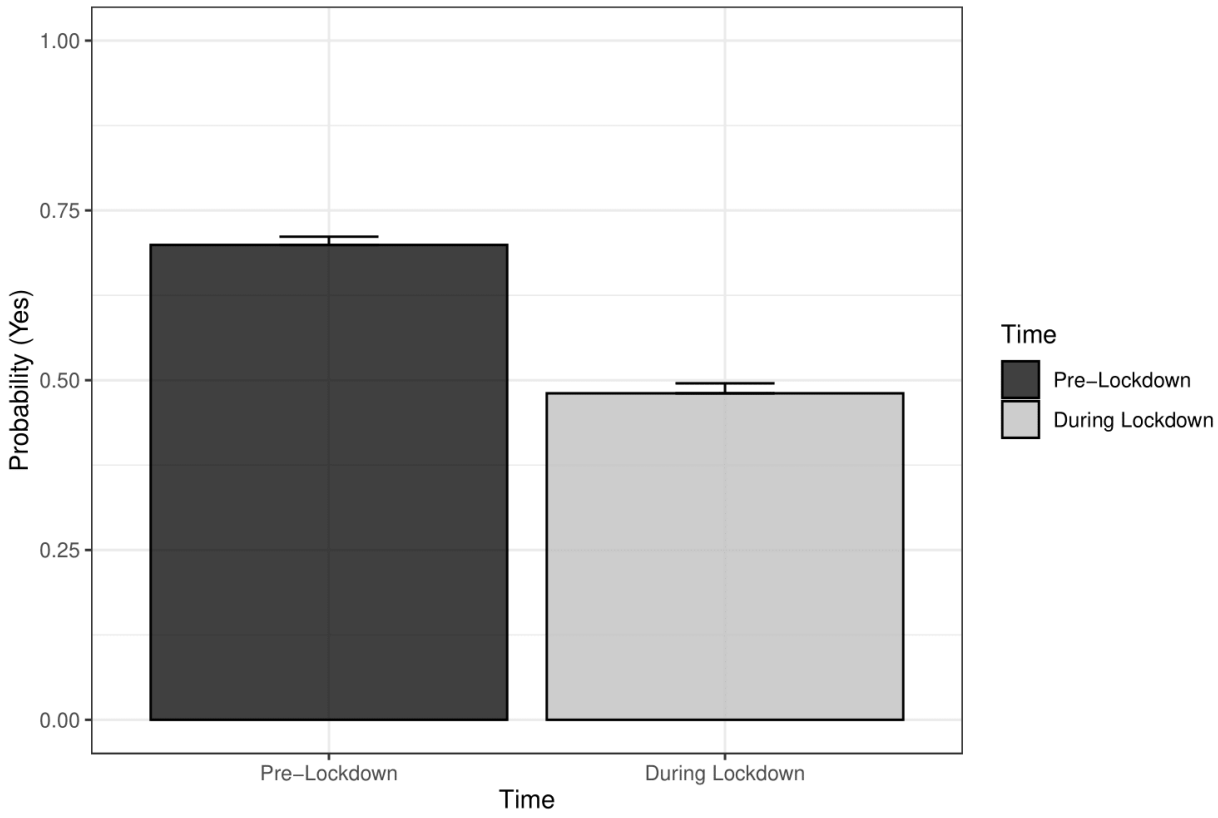

Figure 2. Predicted marginal probabilities for "*Have you previously purchased specific equipment (including weights, machines, bands, or other devices) to support your RT?*" over 'time' (i.e. pre- and during- lockdown). Note: error bars are 95% compatibility (confidence) intervals.

3.2.4 How did you usually train?

The GEE results of this MRCV question are presented in Figure 3. The pattern of probabilities across items was largely similar both pre- and during- lockdown with a considerably higher probability that individuals would be training 'alone' compared with all other options. Notable changes however include slight reductions in both training 'supervised in person' (from ~15% to 2%) and 'with a partner' (from ~32% to 21%). There were slight increases in both training 'supervised virtually/online' and 'video training' but the probabilities of these responses remained low (~5-6% probability).

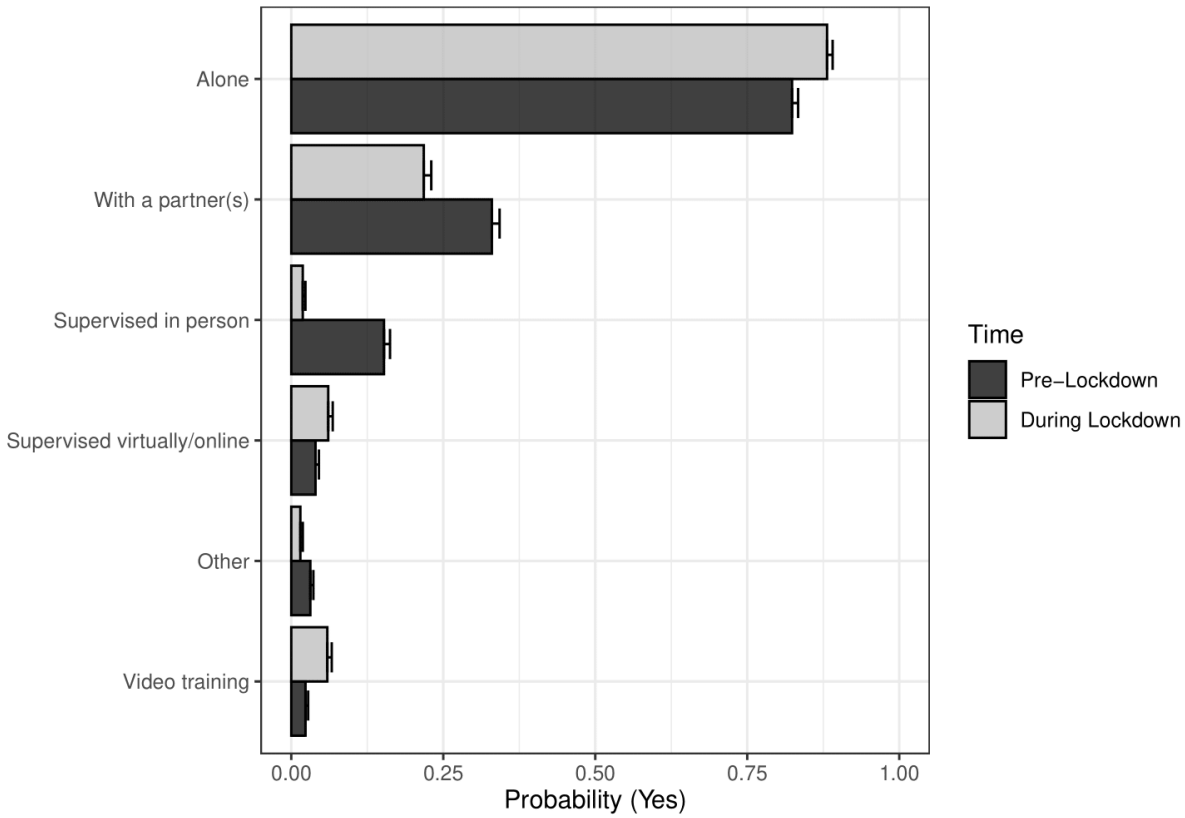

Figure 3. Predicted marginal probabilities for "*How did you usually train?*" over 'time' (i.e. pre- and during- lockdown) and 'items'. Note: error bars are 95% compatibility (confidence) intervals; y axis is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.2.5 Did you usually perform a full body or split routine?

The binomial logistic regression results of this SRCV question are presented in Figure 4. Compared with prior to lockdown (~38% probability), individuals were more likely to be using full-body routines during- lockdown (~51% probability).

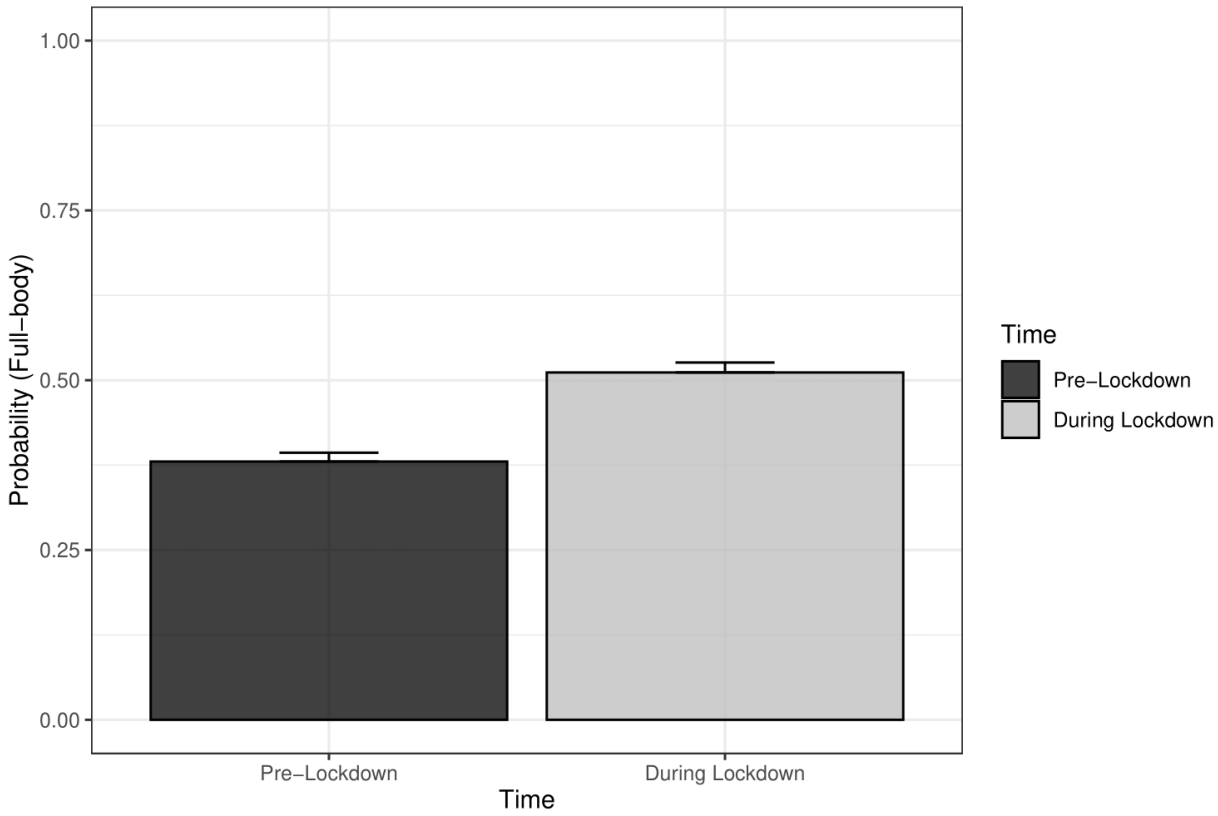

Figure 4. Predicted marginal probabilities for "*Did you usually perform a full body or split routine?*" over 'time' (i.e. pre- and during-lockdown). Note: error bars are 95% compatibility (confidence) intervals.

3.2.6 What types of training did you usually perform?

The GEE results of this MRCV question are presented in Figure 5. Prior to lockdown individuals had the greatest probability of utilising 'free weights' (~95% probability) with relatively similar probabilities of using 'resistance machines' (~66% probability), 'bodyweight exercise' (~61% probability), and performing 'cardio/aerobic exercise' (~55% probability). During- lockdown there was both a slight drop in the probability of using 'free weights' (~80% probability) and a slight increase in the probability of using 'bodyweight exercise' (~83% probability). Finally, there was a considerable decrease in the probability of training with 'resistance machines' (~13% probability).

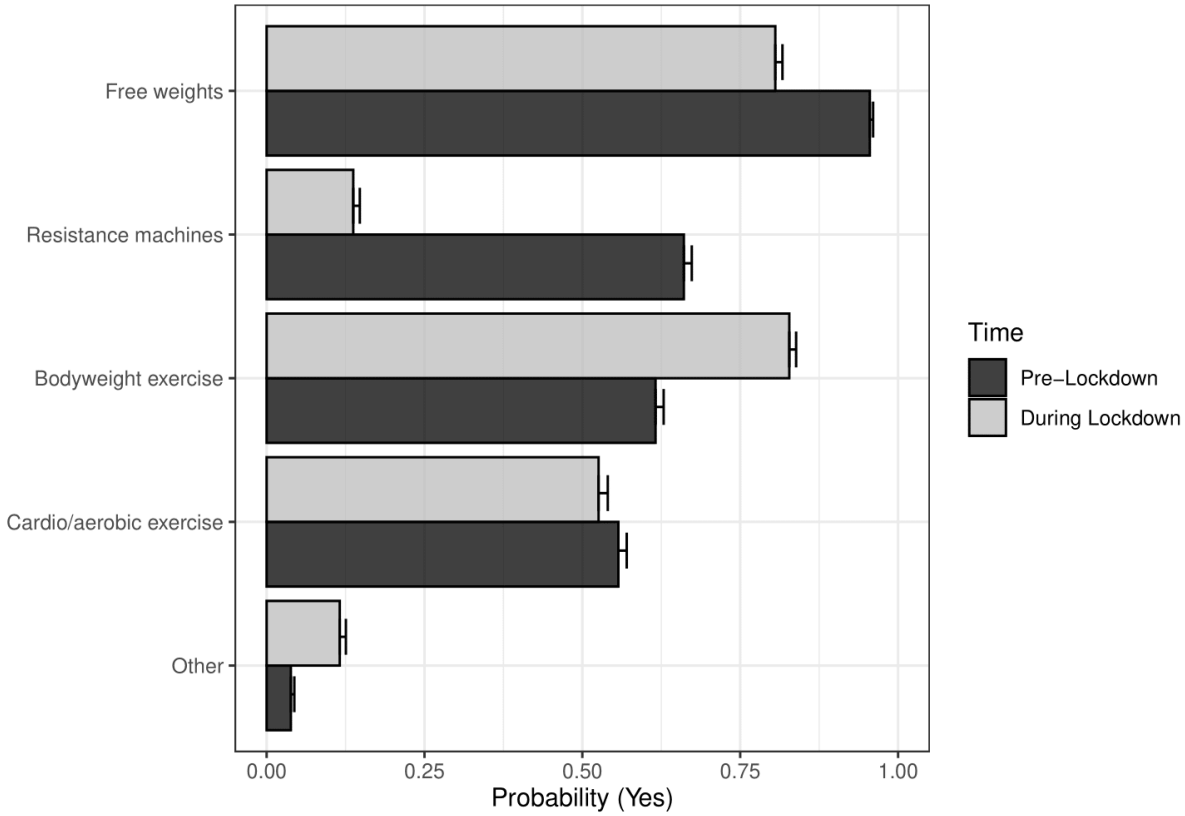

Figure 5. Predicted marginal probabilities for "*What types of training did you usually perform?*" over 'time' (i.e. pre- and during-lockdown) and 'items'. Note: error bars are 95% compatibility (confidence) intervals; y axis is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.2.7 What repetition range/exercises/set volumes did you usually use?

The GEE results of these four MRCV questions are presented in Figure 6. Overall, the patterns for these are comparable from pre- to during- lockdown. An exception to this appears to be with respect to the repetition ranges used with a reduction in the probability of using lower repetition ranges ('1-5 reps' and '6-10 reps'), and an increase in the probability of using very high repetitions ('>15 reps').

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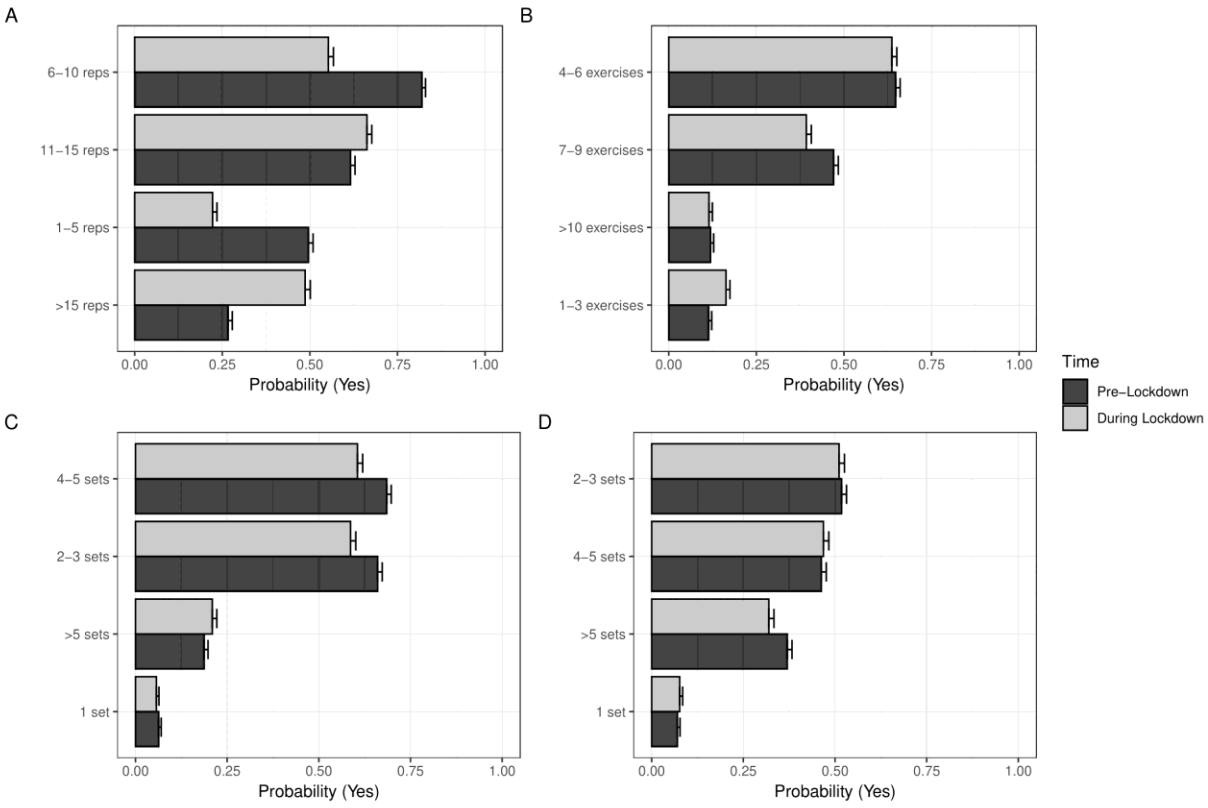

Figure 6. Predicted marginal probabilities for "*What repetition range/exercises/set volumes did you usually use?*" over 'time' (i.e. pre- and during- lockdown) and 'items'. A) shows the repetition range used, B) shows the number of exercises used, C) shows the number of sets per exercise used, and D) shows the number of sets per muscle group used. Note: error bars are 95% compatibility (confidence) intervals; y axis is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.2.8 How often per week did you usually train?

The GEE results of this MRCV question are presented in Figure 7. Overall, the patterns for frequency of training are comparable from pre- to during- lockdown with only a slight yet notable reduction in the probability of training '4-5x/week' (from ~50% to 40% probability).

DOI: 10.31236/osf.io/b8s7e

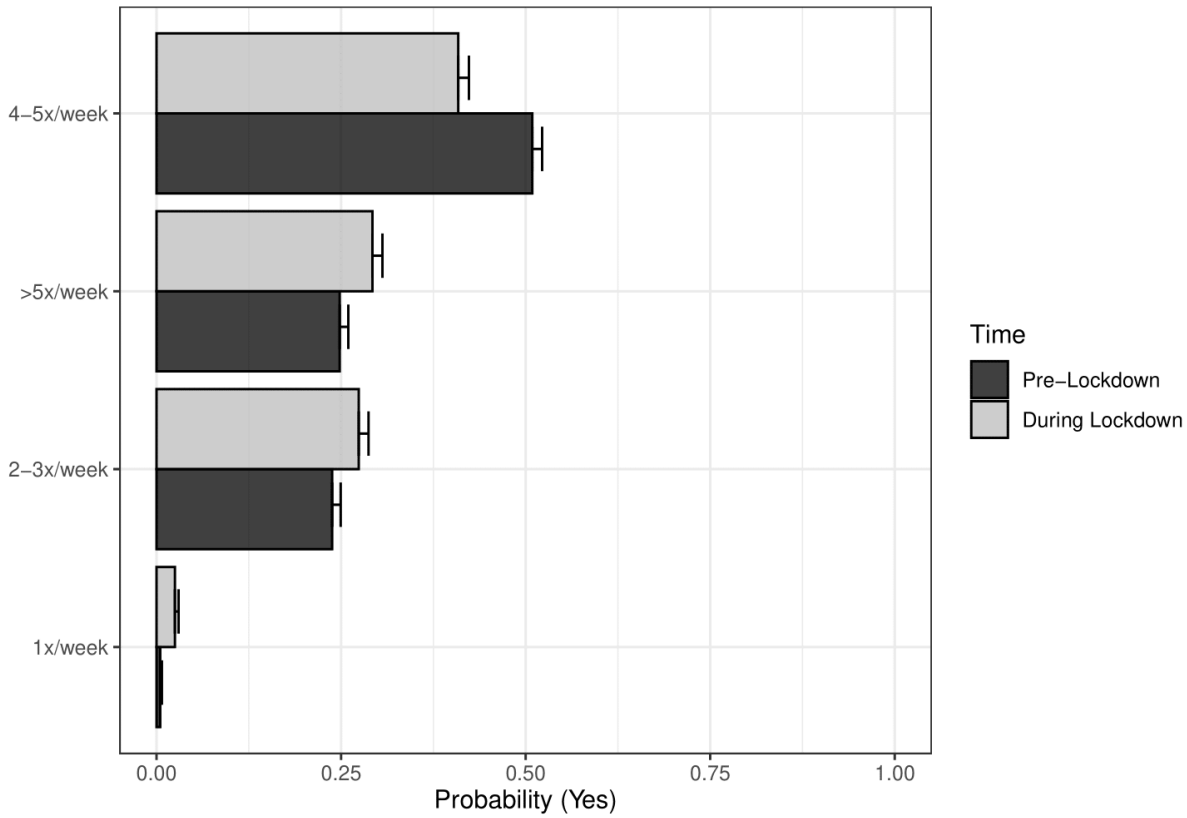

Figure 7. Predicted marginal probabilities for "*How often per week did you usually train?*" over 'time' (i.e. pre- and during- lockdown) and 'items'. Note: error bars are 95% compatibility (confidence) intervals; y axis is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.2.9 What was your usual intensity of perceived effort in your training?

The Wilcoxon signed-rank test yielded a *Z* statistic of 32.313. Rating of perceived effort was reduced from pre- (median = 8) to during- lockdown (median = 7). The effect size for this difference was 'moderate' (*r* = 0.31). Figure 8 shows the paired responses on a scatter plot for pre- and during- lockdown rating of perceived effort scores along with vertical and horizontal lines show the median values for pre- and during lockdown respectively.

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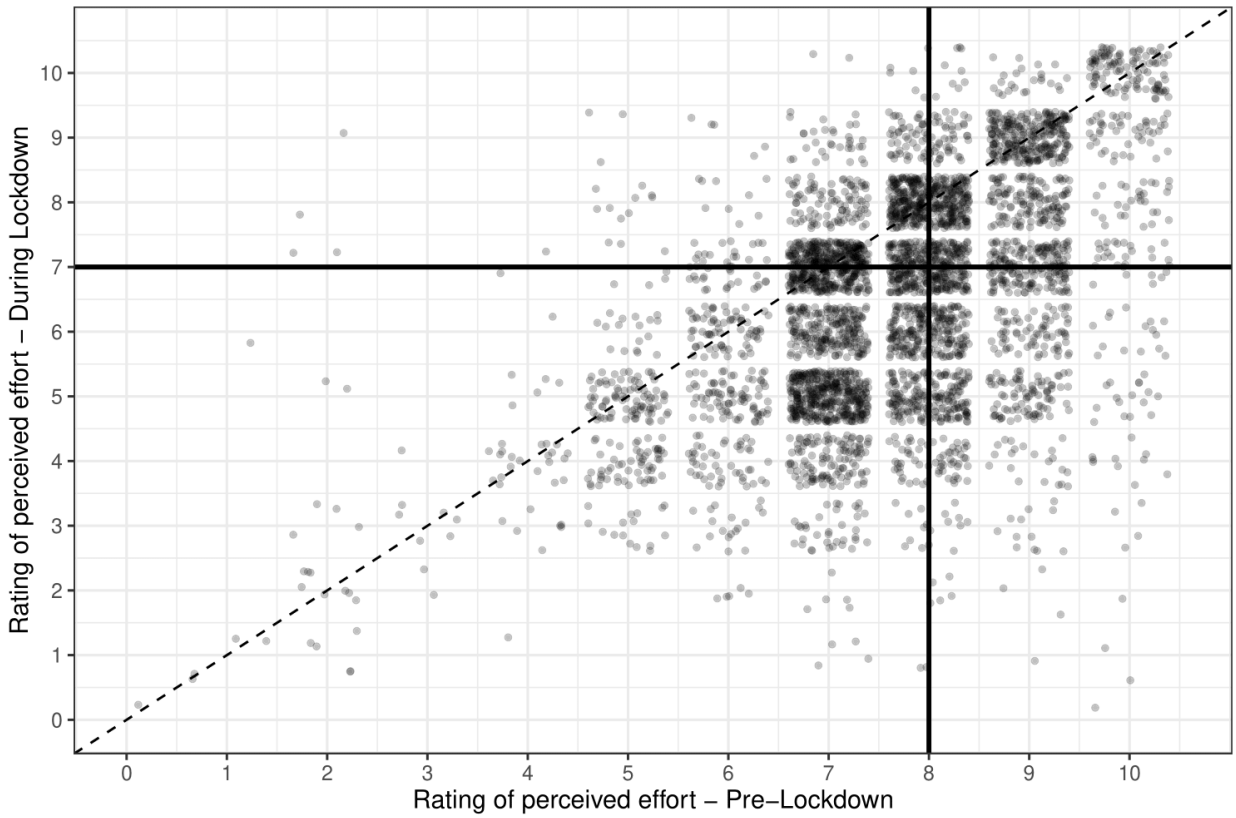

Figure 8. Scatter plot for "*What was your usual intensity of perceived effort in your training?*" over 'time' (i.e. pre- and during-lockdown). Note: the dotted diagonal line is the identity line for reference; the thick vertical and horizontal lines show the median values for 'pre-lockdown' and 'during lockdown' respectively.

3.2.10 Did you usually plan/record each workout?

The GEE results of these two MRCV questions are presented in Figure 9. Overall, the patterns for these are comparable from pre- to during- lockdown with individuals more likely to plan, but not record, their workouts and only a slight reduction in these probabilities during-lockdown.

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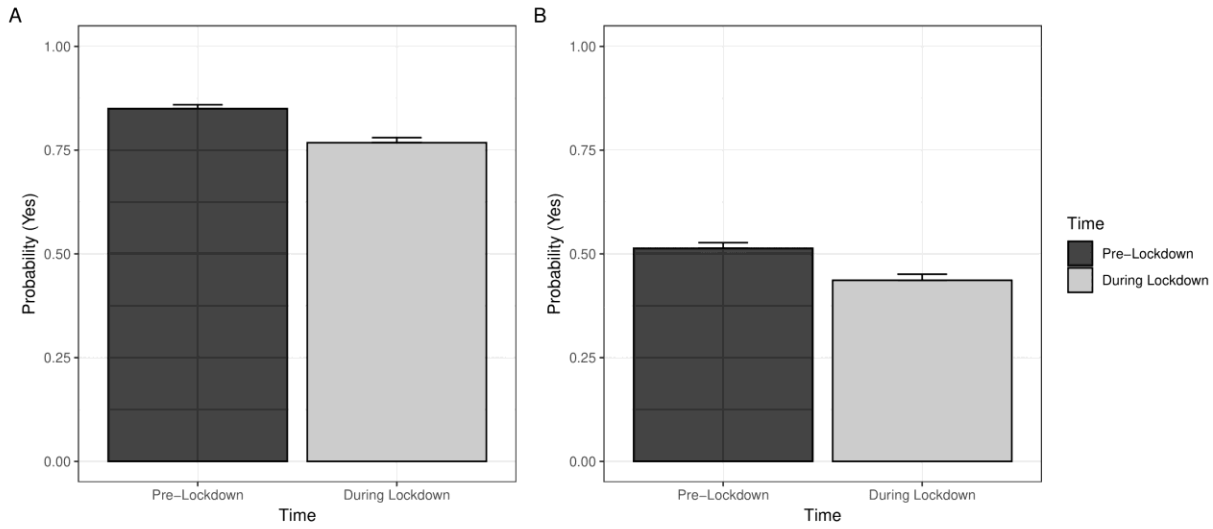

Figure 9. Predicted marginal probabilities for "*Did you usually plan/record each workout?*" over 'time' (i.e. pre- and during- lockdown) and 'items'. Note: error bars are 95% compatibility (confidence) intervals; y axis is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.2.11 Did you usually train in the morning, afternoon, evening or night-time?

The GEE results of this MRCV question are presented in Figure 10. Overall, the patterns for what time of day individuals usually trained are comparable from pre- to during- lockdown with only a slight yet notable increase in the probability of training in the 'afternoon' (from ~43% to 52% probability).

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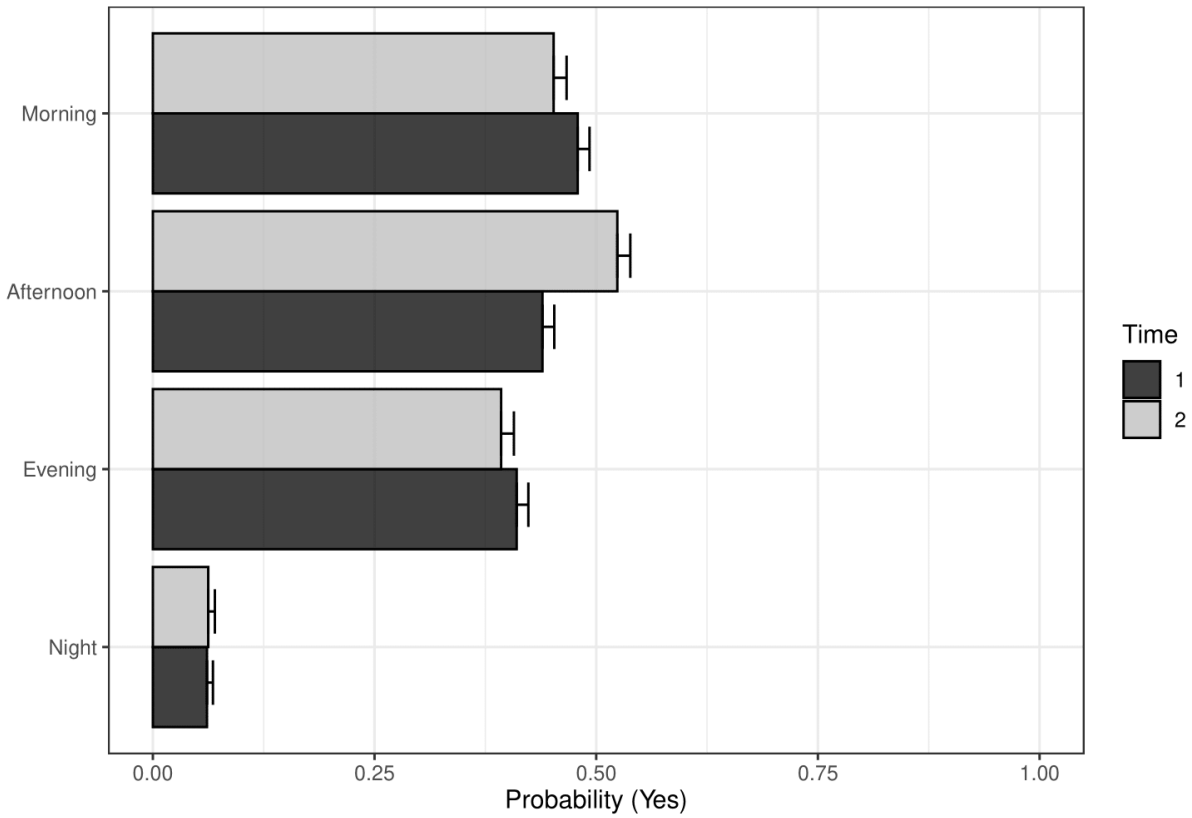

Figure 10. Predicted marginal probabilities for "*Did you usually train in the morning, afternoon, evening or night-time?"* over 'time' (i.e. pre- and during- lockdown) and 'items'. Note: error bars are 95% compatibility (confidence) intervals.

3.2.12 What were your goals from participation in training? (please select all that apply)

The GEE results of this MRCV question are presented in Figure 11. Prior to lockdown the most prominent goal was 'strength' (~83%) whereas during- lockdown this was 'general health' (~77%). Further, a small majority (54%) reported to have maintained the same goals from pre- to during- lockdown.

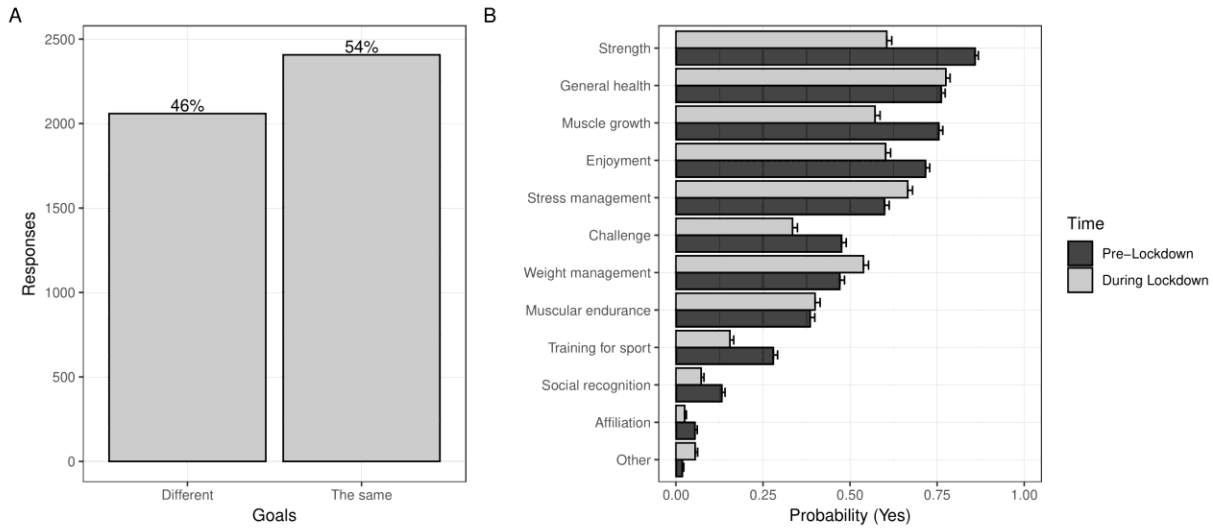

Figure 11. A) shows frequencies and exact marginal probabilities for *"Are you goals for training different/the same?"* as point estimates for questions relating to individuals training goals. B) shows predicted marginal probabilities for "*What are your goals from participation in training?*" over 'time' (i.e. pre- and during- lockdown) and 'items'. Note: error bars are 95% compatibility (confidence) intervals; y axis for B) is ordered by the magnitude of probabilities at 'pre-lockdown'.

3.3 Secondary Outcomes and Exploratory Analyses

3.3.1 Motivation, enjoyment, and likelihood of continuing current training

Frequencies and percentages for questions relating to respondents' current motivations, enjoyment, and likelihood of continuing with current training are shown in Figure 12. For the whole sample, individuals have mostly 'similar' or 'lower' (both 33%) current motivation to train, and for those who had continued training there was notably 'lower' enjoyment (40%). However, most people who continued training said they were 'similarly likely' to continue with their current training (41%).

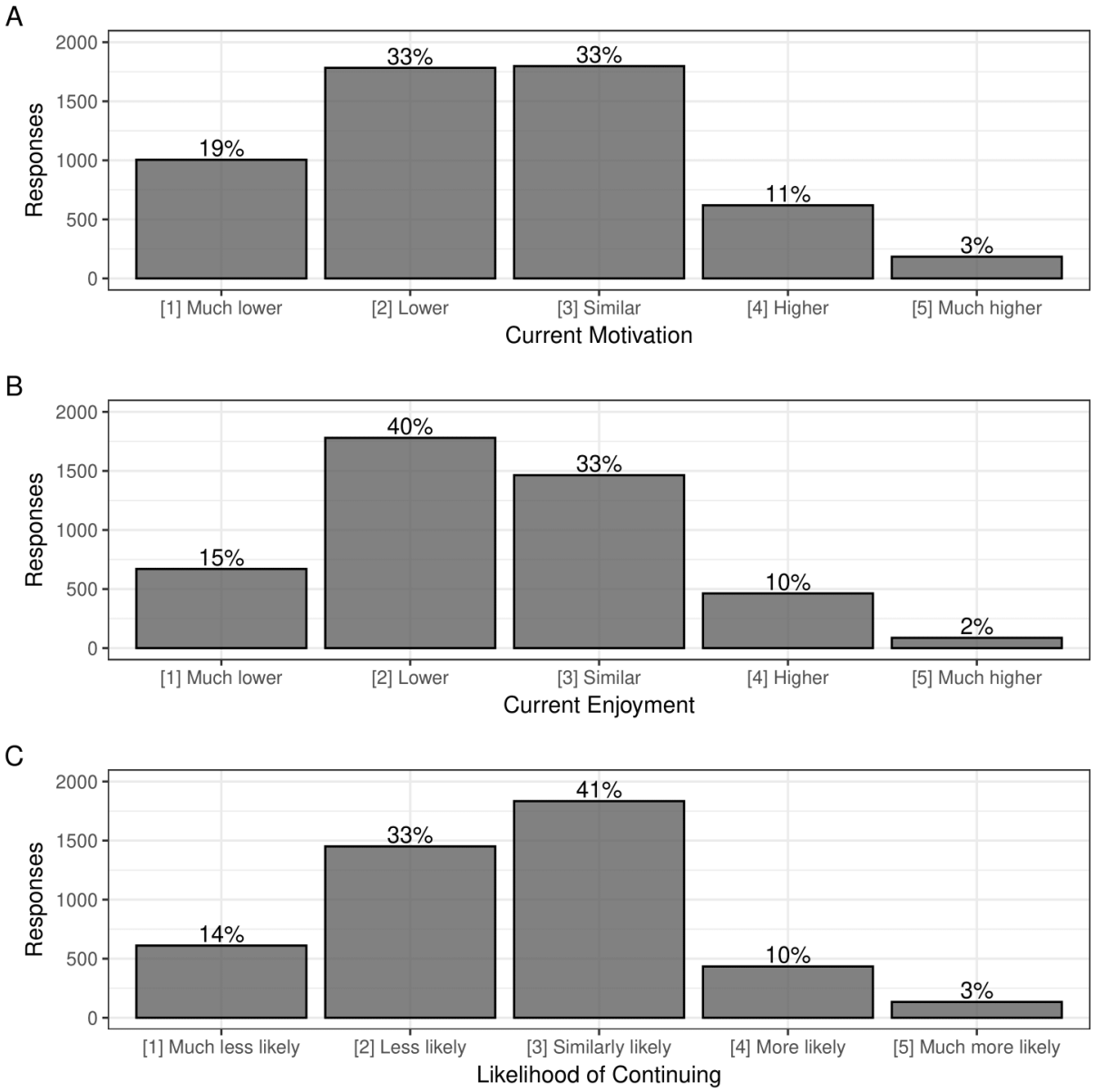

Figure 12. Frequencies and proportions of responses for A) motivation, B) enjoyment, and C) likelihood of continuing training.

3.3.2 Perceived effectiveness

Frequencies and percentages for questions relating to respondents' perceived effectiveness of their current training, with a breakdown based upon whether goals had changed or not, are shown in Figure 13. For those whose goals remained the same a majority indicated they felt that their current training was 'similarly effective' (44%), or 'less effective'

(38%). For those who changed their goals, their current training was mostly perceived to be 'less effective' (54%), though reported similar perceptions of effectiveness for their new goals with the majority reporting their training as 'similarly effective' (42%).

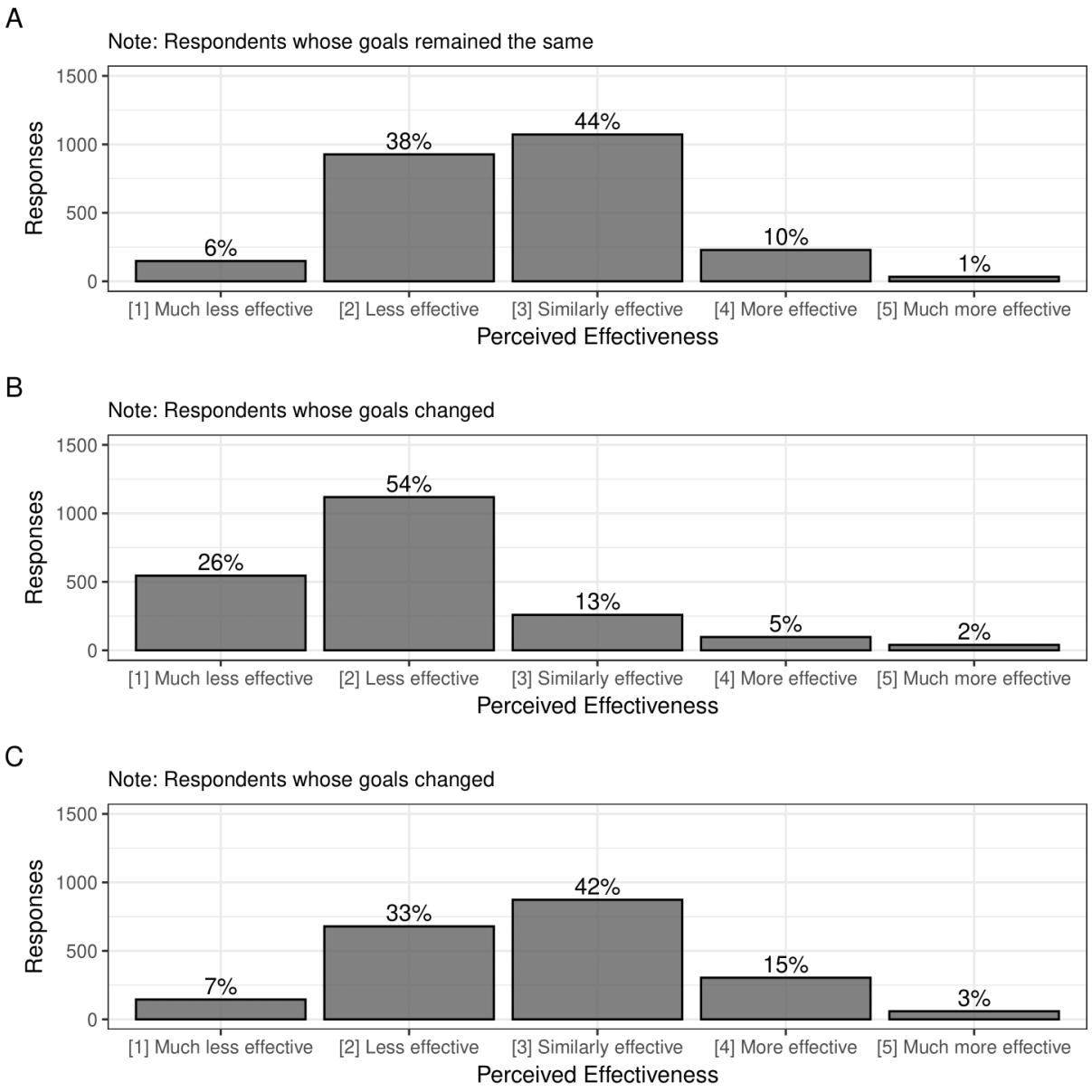

Figure 13. Frequencies and proportions of responses for perceived effectiveness of current training for A) current goals in those whose goals remained the same, B) prior goals in those whose goals changed, and C) current goals in those whose goals changed.

3.4 Exploratory Findings

All exploratory plots are included in the supplementary files (S5 to S24) for readers to examine. We highlight only those exploratory findings that appear noteworthy here.

3.4.1 Demographics predictors of training behaviours

Somewhat surprisingly, there was no clear impact of current motivation on probability of continuing RT. There were some suggestions of demographic predictors for the probability of continuing RT during- lockdown. A slightly greater probability was seen for those who have competed in sports (most clearly for strength sports and endurance sports participation), and a slightly greater probability of continuing with greater years of RT experience. However, across almost all predictors the probability of continuing RT remained fairly high (~70-80%). An exception was a lower probability of continuing for self-identified black respondents (~60%), yet due to the low sample number in this group the interval estimate is imprecise compared to other groups. Exploratory plots of probability of continuing RT are available in supplementary file S5.

There were few clear interactions between demographic predictors and probabilities of RT behaviours over time (i.e. pre- to during- lockdown) with most differences appearing minor. During- lockdown older individuals were slightly more likely to train 'supervised virtually/online' though the probability was still low (supplementary file S8). There was a tendency towards greater probability of purchasing new equipment for those middle aged (supplementary file S7). Interestingly those with greater RT experience were more likely to purchase equipment pre-lockdown, but less likely to do so during- lockdown (supplementary file S7).

Some relationships between predictors and certain behaviours were consistent across both time points. This was most evident for the effects of age, RT experience, and goals; all other associations again appeared minor. With increased age individuals were less likely to train alone yet had increased probability of being 'supervised in person' and decreased probability of training 'with a partner(s)' (supplementary file S8). With increased age it was also more probable for people to perform full-body routines (supplementary file S9), and be less likely to use free-weights but more likely to use resistance machines and perform cardio/aerobic exercise (supplementary file S10). Older individuals were also less likely to use lower repetitions ranges (i.e. 1-5 and 6-10 repetitions), were more likely to use >10 exercises and less likely to use 4-6 exercises, and also more likely to perform single sets of both exercises and for muscle groups (supplementary files S11to S14). There was also a slight increase in probability of training 1x/week, a larger increase in training 2-3x/week, and similar decreases in 4-5 & >5x/week with

increased age (supplementary file S15). Older individuals were also more likely to train in the morning and less likely to train in the afternoon or evening (supplementary file S20), and their goals were more likely to be muscular strength, endurance, or general health, and less likely to be muscle growth, enjoyment, or social recognition (supplementary file S21). Interestingly, both weight and stress management as goals showed inverted U-shaped relationships with the greatest probabilities occurring during middle age (supplementary file S20). Many of the relationships with age were similar for RT experience likely due to their covariance. Goals were unsurprisingly associated with certain predictors; for example, having competed in strength sports, bodybuilding, and endurance sports were associated with greater probability of having muscular strength, growth, and endurance as goals (supplementary file S20). Those with higher BMI were also more likely to report weight management as a goal, men were more likely to report muscle growth, and women were more likely to report weight management, general health and stress management (supplementary file S20).

3.4.2 Impact of RT behaviours upon perceived effectiveness of training, enjoyment from training, and likelihood of continuing training

With the exception of training frequency, there were not any apparent relationships between specific RT behaviours during- lockdown and perceived effectiveness of training, enjoyment from training, and likelihood of continuing training (supplementary files S21 to S23). Those who were training 1x/week were somewhat more likely to perceive their training as less effective, less enjoyable (and those with higher frequencies reported more enjoyment), and were less likely to continue their current training. When looking at the breakdown across whether goals changed or not, for those who changed their goals during- lockdown current training was perceived to be less effective for both prior and current goals, and those who changed goals generally found training less enjoyable and were less likely to continue their current training.

4.0 Discussion

We found that the practice of RT, in those who previously self-identified as regularly engaging in RT, was largely unaffected (albeit with slight adaptations to certain behaviours) by various lockdown protocols that included closure of gyms and leisure facilities (i.e. the implementation of facility closures AND/OR social distancing). A majority of individuals (82.8%) maintained participation in some form of RT during- lockdown and on the whole the probabilities of engaging in certain RT behaviours were largely similar (particularly numbers of exercises, sets per exercise or muscle group, and weekly frequencies). We did note some

alterations in RT practice, however, including: a shift from primarily training in privately owned gyms to training at home; greater probability of training using a full-body routine; a reduction in use of resistance machines and an increase in free weight and bodyweight training; a reduction in use of moderate repetition ranges and greater use of higher repetition ranges; and a reduction in the perception of effort experienced during- training. Further, individuals were slightly less likely to plan or record training during- lockdown and many changed their training goals as a result of lockdown. For those who changed their training goals, their current training was perceived as less effective for their prior goals, though for their current goals it was mainly perceived as similarly effective as was training for those who did not change their goals. Overall people's motivation to train was similar, or lower; enjoyment from training was mostly lower; and people were similarly likely to continue with the training they were conducting during-lockdown. Interestingly there were few obvious interactions of any demographic predictors and the impact of lockdown; however, there were some possible effects across time from age, RT experience, and training goals.

Those previously engaged in RT appeared largely able to maintain similar training behaviours (numbers of exercises, sets per exercise or muscle group, and weekly frequencies), yet adapted to performing their training within new locations and with alternate modalities. The shift to primarily home-based training is unsurprising given the facility closures and social distancing protocols implemented, and it may be that resistance training was more easily adapted to home environments compared to endurance training. Though the change in location may have implications such as loss of the typical psychosocial benefits of the gym environment [13], and also access to certain equipment (i.e. resistance machines), evidence suggests that a range of modalities of RT are broadly speaking similarly efficacious [34-37]. Free weight[10] and bodyweight exercises were the most common modality used during- lockdown, in addition to a shift towards use of higher repetition ranges which may reflect the use of lower loads perhaps due to the difficulty of accessing and storing large amounts of free weights, in addition to the use of bodyweight exercise. Evidence suggests that both heavier-and lighter-load RT can produce similar adaptations in both general strength and muscular growth [34]; and further,

[10] Perhaps facilitated by many individuals already having access to such home equipment; as evidenced by a greater probability of having purchased equipment prior to lockdown. Based upon the wording of this question responses may in fact reflect those purchasing equipment in preparation for the coming lockdown to facilitate continued training at home. Indeed, those with more RT experience were more likely to purchase pre- lockdown, but less likely during- lockdown. Due to the surge in purchases of home-based equipment leading into and early on in lockdown, shortages were commonly reported during- lockdown rendering it difficult to make purchases during- that period and indeed after an initial spike demand dropped [17]. Those with greater RT experience may have better anticipated this.

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when employed in a similar manner (as appears to have been done by respondents in this study), a variety of modes of external resistance appear to produce largely similar outcomes [34-37]. Thus, although many perceived their training to be less effective during- lockdown, evidence suggests that engagement was likely similarly efficacious.

Despite the relative stability of training behaviour, one clear difference in the manner in which RT was being performed was with respect to intensity of effort. On average there was a 'moderate' drop in rating of perceived effort based upon the standardised effect size (though this was only 1pt on the 11pt scale used). Studies of athletes during this period have reported similar reductions in perception of effort for training [38,39]. This may have implications for the efficacy of RT given the important role that effort may play in determining outcomes [2,40]. This outcome may be explained, at least in part, by fears of immunosuppression and subsequent risk of infection considering the 'open window' theory and the dose-response impact of intensity of effort [24,41]. Perhaps a more salient factor though may be motivation; indeed, current motivation for training was skewed towards being lower during- lockdown. Motivation is thought to be a determinant of the intensity of a given behaviour engaged in (i.e. effort [42]) and an unplanned exploratory analysis of our data[11] suggested there was a relationship between current motivation and the change in rating of perceived effort (i.e. during- minus pre-lockdown). Those who were more motivated were more likely to maintain their training effort.

Reporting of lower motivation for current training was accompanied by other corroborating factors such as a reduced likelihood of engaging in planning of RT behaviours. These effects could be explained under several theories. Within the Theory of Planned Behaviour, perceived behavioural control is thought to be a key component in determining engagement in exercise including RT [43]. Further, within Social Determination Theory there is evidence of consistent relationships between autonomous motivations, goals, and exercise engagement [43]. Indeed, choice and the ability to be autonomous has been proposed as important for successful engagement in RT, increasing enjoyment, adherence, and its benefits [45]. Notably, respondents typically reported lower enjoyment as well. The clearest impact upon perceived effectiveness, enjoyment, and likelihood of continuing training however was upon those who had changed their training goals. Frequency was also a factor in this regard, as those training 1x/week were somewhat more likely to perceive their training as less effective and less enjoyable, and were less likely to continue their current training. In contrast, those exercising at higher frequencies reported more enjoyment. Indeed, frequency appeared to be associated with

[11] See supplementary file S24

motivation also in an unplanned exploratory analysis[12] and thus lower engagement might have been a result of reduced motivation. Lockdown likely forced people to change their training habits thus impacting upon their perceptions of autonomy and control. This was most influential for those who also changed their training goals, perhaps through necessity of the enforced lockdown impacting behaviours, who felt that their new training was less effective for their previous goals and thus shifted those goals to something it would be effective for. It did not seem that any specific aspects of training behaviour changes were particularly influential. While previous work has indicated that a shift towards free weight use could increase enjoyment compared to resistance machines [46], we found no impact of modality of training on enjoyment. Thus, loss of control of training was likely the more impactful factor upon people's perceptions, intentions, and engagement.

The general resilience of RT behaviours to the lockdown warrants further examination of those who stopped training during- lockdown at follow-up to understand whether this was a temporary behaviour change, or longer term. Considering the Transtheoretical Model of behaviour change, recommencing a positive behaviour such as exercise is typically challenging after it is broken (i.e. 'relapse' [47]). However, though facilities have begun to reopen in many countries, reviews of consumer confidence surveys show varying intentions to return to using gyms [17]. Some evidence suggests that with new guidelines for hygiene and social distancing, gym reopening may not increase risk of COVID-19 spread [48]. Of the 923 individuals in our study who said they had stopped training, 663 (72%) consented to be contacted for a follow up survey. Thus, future work will explore whether individuals in our survey who ceased RT return to participation.

4.1 Strengths and limitations

A strength of this study was the speed with which we were able to implement the surveys (including translations) and the sample size achieved. However, the predominant demographic represented was white US males thus potentially affecting the generalisability of the findings. Indeed, a large proportion were also educated to University level in a topic related to physical activity, exercise, or sport which might be expected to facilitate resilience in RT behaviours. Further, relatively few were care-givers which would be expected to influence ability to maintain RT behaviours. History bias may be a potential concern in interpreting the effects of implementation of lockdown policies in pre- to during- analyses. However, our screening excluded those who were not currently subject to such measures and so imposed some control

[12] See supplementary file S25

for the impact of varying policies between countries. One factor which was not controlled for however was the time since lockdown began and thus the potential for recall bias, or for short term changes in behaviour for those who had been under lockdown for longer periods (up to ~5 weeks).Though it could be considered a strength with respect to the population sampled (i.e. resistance trained individuals), sampling bias due to the distribution of the survey through the authors' social and professional networks may further limit the extent to which inferences can be generalised to the general population of those engaged in RT. Lastly, due to the urgency of responding to the implementation of lockdown, our survey was developed *ad hoc* and did not undergo any psychometric validation process. However, given the specific expertise of the research group in RT we felt confident in the face validity of the questions, particularly relating to relevant RT behaviours. As a research group we in essence followed, albeit informally, approaches to expertise development and validation of surveys [49]. Further, although we were able to translate into several languages with the inclusion of an international multi-lingual research group, we did not have sufficient time to engage in more robust forward and backwards translation [50].

5.0 Conclusions

Those engaged in RT prior to the COVID-19 lockdown appeared mostly able to maintain these behaviours with only slight adaptations in both the location and types of training performed (i.e. home-based free weight and bodyweight training). However, people employed less effort, and motivation, perceived effectiveness, enjoyment, and likelihood of continuing current training all appeared lower during- lockdown which may have resulted from a loss of control and autonomy in goal selection and behavioural choices. These results have implications for strategies to maintain engagement in positive health behaviours such as RT during-restrictive pandemic-related public health measures. It is unclear what the long-term effects of lockdown will be upon behaviours (including for those who stopped training) and perceptions and so future work will follow-up the cohort in this study.

Contributions

JS, JPF, LC, BJS, SP, RW, DW, DS, and PAK conceived and designed the study. TA, SD, MVF, FS, TRL, PG, TK, JG, MS, and AP contributed materials and translations or survey tools. JS performed the data cleaning and analysis. All authors interpreted the results. JS and BJS drafted the initial manuscript. All authors edited and finalised the manuscript.

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Data and Supplementary Material Accessibility

All materials, data, and code are available on the Open Science Framework project page for this study https://osf.io/xhryf/

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