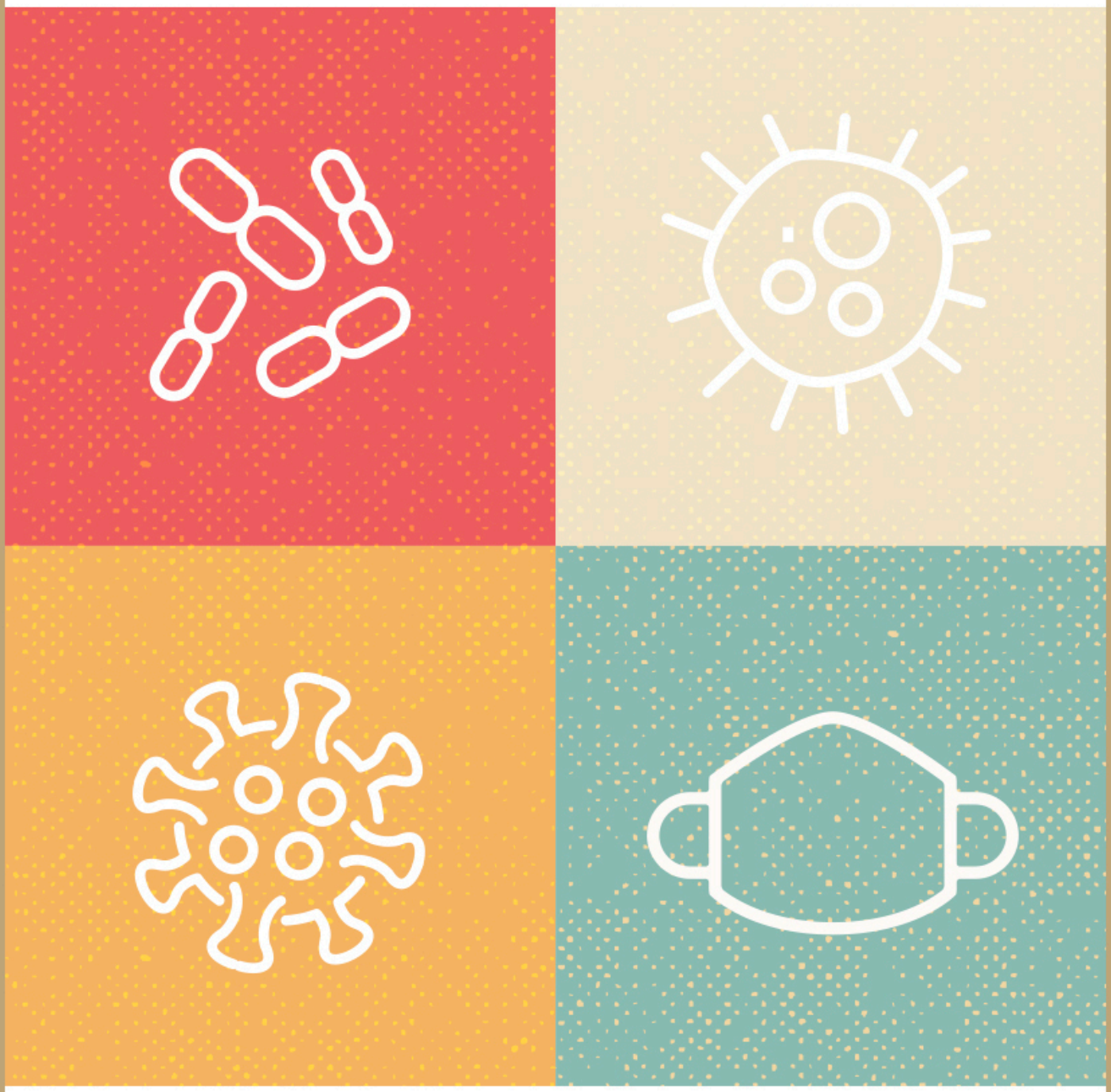
CommonHealth

A Journal of the College of Public Health at Temple University



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About the Journal

CommonHealth, a journal of the College of Public Health at Temple University, is a peer-reviewed, online-only, open access journal for rapid dissemination of high-quality research and scholarship related to all aspects of public health. The journal publishes papers of interest to public health scholars in academic, clinical, government and industry roles working on all aspects of major public health issues.

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ORIGINAL RESEARCH
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An Analysis of Sleep and Ergometer Performance in Collegiate Male Rowers

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***Introduction**: Research has increasingly examined the effects of sleep on athletic performance. Although there is substantial evidence for the detrimental effects of sleep deprivation on athletic performance, few studies have assessed the effects of sleep extension, and most are limited to field or team sports. Additionally, existing sleep extension studies largely exclude sports such as rowing which traditionally have early practice times and therefore represents a population at heightened risk of sleep deprivation. The purpose of the present study is to determine whether sport specific performance benefits are gained when collegiate rowers extend their sleep.* ***Methods**: Nineteen members of the Temple University men's rowing team were asked to increase their sleep to nine to ten hours (540-600 minutes) a night for four weeks, following a two-week baseline period. A two-week post-intervention phase followed the sleep extension period. In addition to daily heart rate variability, three sport-specific measures – related to peak rowing power and pace – were obtained weekly using a rowing ergometer.* ***Results**: Subjects were unable to extend their sleep from baseline during the intervention phase, 392.07 ± 53.69 minutes and 374.11 ± 41.53 minutes, respectively ($p = .137$). Significant variation was found in the week to week comparison of the Interval test and OR1-Min test.* ***Conclusion**: Since athletes failed to increase their sleep time, we were unable to examine the impact of sleep on performance. It is likely that athletes require more education or access to other strategies to develop the habits necessary for increased sleep. Changes in performance from baseline could be attributed to unmeasured variables, such as stress, nutrition, or changing workload in training.*

Introduction

Sleep deprivation and restriction on athletic performance has been central in sleep literature focused on athletics for the past few decades. Studies have questioned the effects of sleep deprivation on athletes and performance in varying age groups, sports, and ability levels. Studies have consistently reported findings of detriment to performance in endurance events, such as time to exhaustion and time trial events, and in power sports such as powerlifting and sprinting. Similar results have been found across the spectrum of talent when athletes are subjected to mild to severe sleep deprivation.[1-6] Conversely, few studies explore the effects of sleep extension and increased total sleep time on athletic performance. Widely cited research out of Stanford University found significant improvements in sport specific skills, mood, and hand-eye coordination following and during an eight-week sleep extension study with collegiate basketball players.[7] Since that publication, several other studies have found similar results in sports such as rugby, soccer, and tennis to those in the Stanford study.[8,9]

Athlete monitoring and biofeedback has provided a new, technology driven method for training high level athletes. Heart rate variability (HRV), a measure of the change in time between consecutive heartbeats, or the R-R interval, has been shown to be an accurate predictor of recovery.[10] HRV is a

reflection of vagal nerve activation which controls parasympathetic and sympathetic nervous system activity.[11] Higher HRV values generally correlate with greater health and recovery while lower values with worse recovery and greater risk of injury and illness.[12-14] As sleep is the primary time when mental and physical recovery occurs, daily HRV recordings provide an objective measure of the recovery quality from the previous night of sleep.

The ability of an athlete to recover will directly influence how well they will perform on consecutive days of practice and competition.[15,16] Effectively monitoring how long it takes an athlete to recover from a training session or competition can give insights into the training strategies being used and what modifications may be needed.[17] Utilizing HRV as a method of monitoring fatigue and "readiness" in athletes and teams correlates with performance and injury risk in a host of different athletes, suggesting a simple and cost effective tool for coaches.[17-19]

Rowing is a sport with unique physical requirements, with athletes requiring both high levels of endurance as well as strength. As a sport with traditionally early practice and race times, athletes often do not obtain the recommended seven to nine hours of sleep each night.[20] With sleep deprivation a known hindrance to performance, observing these athletes obtaining eight or more hours of sleep each night will provide continued insight into both the effects of sleep deprivation, as well as the effects of recommended and extended amounts of sleep. As an underserved and physiologically different group of athletes, rowers provide a unique population for expanded work on sleep extension.

This study aims to determine whether a period of sleep extension leads to improvement on ergometer performance in collegiate male rowing athletes. We hypothesize that there will be improvement on the rowing ergometer performance as a result of sleep extension and that HRV will increase as sleep increases.

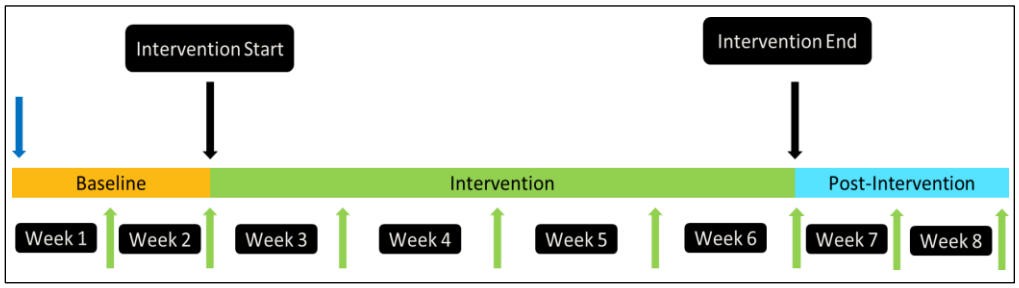
Methods

Nineteen rowers from the Temple Men's Rowing team elected to participate in this study. To assess natural changes in sleep, all participants were to refrain from any caffeine consumption and to avoid the use of diphenhydramine containing sleep aids such as ZzzQuil© or supplements such as melatonin. Any participants who were taking prescribed or over-the-counter medication that affected sleep were excluded from this study. Alcohol consumption was prohibited. Participants were excluded if they had any sleep disorders. Screening was done using three validated questionnaires to assess daytime sleepiness, sleep quality, and sleep apnea risk; the Epworth Sleepiness Scale, the Pittsburgh Sleep Quality Index, and the STOP-Bang.[21-23]

Prior to participation, all subjects were given material pertaining to the specific aims and goals of the study and all subjects provided written informed consent. Ethical approval for this study was given by the Temple University Institutional Review Board.

This eight-week study employed a three phase within-subjects study design (Figure 1). Data collection began at the start of the 2019 spring semester with a two-week (13 night) baseline period. At the start of the third week, participants were instructed to increase their sleep to a minimum of nine hours each night for four weeks. If subjects were unable to achieve this amount of sleep each night, they were instructed to make up the rest of the time through naps during the day. Following the four-week sleep extension intervention, subjects returned to baseline levels of sleep for another two-week period.

Figure 1. Study Timeline



Note: Blue arrow represents Informed Consent and administration of screening questionnaires. Green arrows indicate data collection and compilation for the proceeding week. Baseline consisted of Weeks 1 and 2, Intervention Weeks 3 through 6, and Post-Intervention consisted of Weeks 7 and 8. Each week, sport specific measures of performance, daily HRV, and total sleep were recorded and given a weekly average for each participant. Each participant performed and reported two weekly sport specific measures of performance (Table 1).

Table 1. Outcome and Sleep Measures at Weekly Intervals

	Week 1			Week 2			Week 3			Week 4			Week 5			Week 6			Week 7			Week 8		
	N	Avg	SD	N	Avg	SD	N	Avg	SD	N	Avg	SD	N	Avg	SD	N	Avg	SD	N	Avg	SD	N	Avg	SD
OR1-Min (W)	0			10	798.8	79.87	4	718.5	70.56	10	774.2	101.49	5	781.8	92.39	8	782.63	132.83	9	749.89	143.14	5	727	144.71
RC1-Min (W)	0			13	470.62	47.95	13	461.23	53.96	13	459.69	49.68	11	464.27	42.03	11	466.09	60.63	12	466.42	51.48	9	471.33	48.98
Interval Test (W)	0			11	444.45	36.1	12	415.5	59.25	13	402.23	42.42	10	435	29.81	8	419.63	37.18	10	432.3	34.73	9	442	32.62
HRV (ms)	12	119.26	50.05	11	111.92	53.51	13	118.68	58.62	13	133.74	78.24	12	152.64	83.1	11	125.54	71.48	11	131.02	56.78	9	117.5	61.6
TST (min)	11	408.52	60.53	13	385.65	53.7	13	383.91	45.45	12	387.84	50.6	12	371.06	38.78	8	370.13	36.34	9	372.24	31.58	10	364.1	41.49
TIB (min)	11	480.65	52.28	13	477.53	51.93	13	450.08	128.13	12	482.69	65.63	12	475.47	57.94	8	496.77	45.23	9	465.19	26.49	10	447.17	34.41

Note: OR1-Min = Open Rate 1 Minute Test; RC1-Min = Rate Capped 1 Minute Test; HRV = Heart Rate Variability; TST = Total Sleep Time; TIB = Time in Bed. All significant changes are highlighted in yellow. Significant changes in ORI-Min were found between Weeks 2 and 3, and Weeks 3 and 5 ($p < 0.05$). Significant changes in the Interval Test were found between Weeks 4 and 8 ($p < 0.05$).

Sport Specific Tests

Measurements of rowing performance were collected weekly through an Open-rate 1-Minute test (OR1-Min), a Rate-capped 1-Minute Test (RC1-Min) and an Interval Test (Interval). The two 1-minute tests are variations on peak power testing common in the rowing community. The Interval test is a modified version of a 2000-meter predictor workout, 6x500m intervals. All three tests were on a Concept 2 Rowing Ergometer (Concept2, Morrisville, VT). The OR1-Min was a maximal 1-minute effort. No guidance was given to pacing. Total output was measured in average wattage.

The RC1-Min was a maximal effort one-minute test at a controlled stroke rate or rhythm of 30 strokes per minute (spm). Total output was recorded in average wattage. For the Interval Test, participants were directed to perform three maximal effort 90 second intervals with two minutes rest between each. There was no designated stroke rate for this test. The average wattage over the three intervals was recorded. To minimize confounding factors, testing was prescribed for a specific day of the week; Wednesday for the OR1-Min and RC1-Min and Friday for the Interval test. Participants could select what time of day they wished to complete the testing to accommodate class schedules.

Baseline testing for OR1-Min, RC1-Min, and Interval tests were performed during Week 2. All data points are represented as the average value of each study week, with subjects who reported 75% or greater of their data each week included in analysis. Measurements of rowing performance were collected weekly through an Open-rate 1-Minute test (OR1-Min), a Rate-capped 1-Minute Test (RC1-Min) and an Interval Test (Interval). The two 1-minute tests are variations on peak power testing common in the rowing community. The Interval test is a modified version of a 2000-meter predictor workout, 6x500m intervals. All three tests were on a Concept 2 Rowing Ergometer (Concept2, Morrisville, VT). The OR1-Min was a maximal 1-minute effort. No guidance was given to pacing. Total output was measured in average wattage.

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Baseline testing for OR1-Min, RC1-Min, and Interval tests were performed during Week 2. All data points are represented as the average value of each study week, with subjects who reported 75% or greater of their data each week included in analysis.

Sleep recordings were collected by the subjects on a nightly basis using a SleepScore Max device (SleepScore Labs, Carlsbad, CA). The SleepScore Max uses ultra-wide band, comparable to ultra-low energy radar, to track the movement and respiration of an individual in bed.[24] A validated technology against both actigraphy and polysomnography.[25] Data collection started when the subject turned the lights out and ended when they woke up the next morning. Total Sleep Time (TST) and Time in Bed (TIB), or the total length of a recording, were assessed on a daily and weekly basis. If subjects were unable to obtain 9 hours of sleep at night, they were encouraged to nap during the day for the remainder of the time. TST and TIB values for naps were collected using the SleepScore Max and added to the TST and TIB from the previous night for cumulative minutes. For analysis, participants who recorded four or fewer nights of sleep during a given week were excluded from the weekly analysis of that week.

Daily HRV Recording

HRV data was collected each morning through the HRV4Training smartphone app, validated in several peer reviewed studies, using photoplethysmography (PPG).[26-29] Following standard procedures, upon waking, the participants were to sit up comfortably in bed and take their morning HRV. Subjects were instructed to cover the camera lens and camera light of their smartphone device with their finger. The HRV4Training app software uses PPG to detect the changes in blood flow by illuminating the skin and measuring changes in light absorption. Once a strong PPG signal was established, subjects were instructed to sit still, breathing normally, for 60 seconds. Following the collection of the HRV measurement, participants were prompted to complete a short questionnaire of subjective measures of sleep, stress, fatigue, motivation, and lifestyle. Ratings were on a sliding Likert-type scale. If a subject failed to record a minimum of three HRV readings in a given week, their data was not considered statistically viable and was dropped from analysis for that week.[30]

Baseline values for HRV, TST and TIB are based on the average of Week 1 and Week 2 for each variable (Table 1). All data points are represented as the average value of participants who met the requirements listed above for minimum data collection (see Table 1).

Statistical Analysis

A power analysis run prior to data collection to determine appropriate sample sizes for the study concluded 18 participants were needed to have sufficient power for analysis. One-way ANOVA for repeated measures with a Bonferroni post-hoc analysis was run on the weekly averages of our outcome variables, OR1-Min, RC1-Min, Interval, and HRV to determine week to week variability in outcome measures. Statistical significance was set at $p<0.05$. Analyses and figures were performed and produced using SPSS software (Version 26, IBM Corp, New York, NY, USA) and Microsoft Excel 2017 (Redmond, WA, USA).

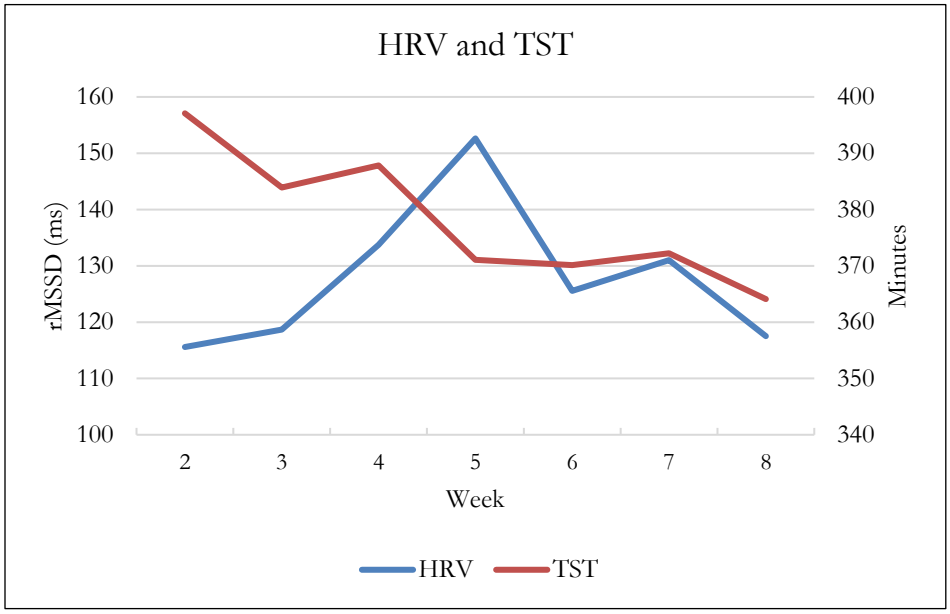
Results

Of the 19 initial participants, five (26%) dropped out. Three due to an inability to follow the sleep extension protocol. One was lost to follow-up, and one was dropped in the fourth week of the study due to starting medication that affected sleep; their data was retained until Week 4. At study completion our n = 14, average age = 19.14 ± .77 yrs, average height = 183.42 ± 5.99 cm, and average weight = 80.21 ± 9.22 kg.

The average results for each week of the study for OR1-Min, RC1-Min, HRV, TST, and TIB are reported in Table 1. There was no significant change between baseline and intervention TIB but there was a non-significant reduction in TST of 18 minutes during intervention (392.07 ± 53.69 vs. 374.11 ± 41.53, p = .137) (Figure 2). There was an increase in HRV during intervention but no significant differences between weeks (Figure 2).

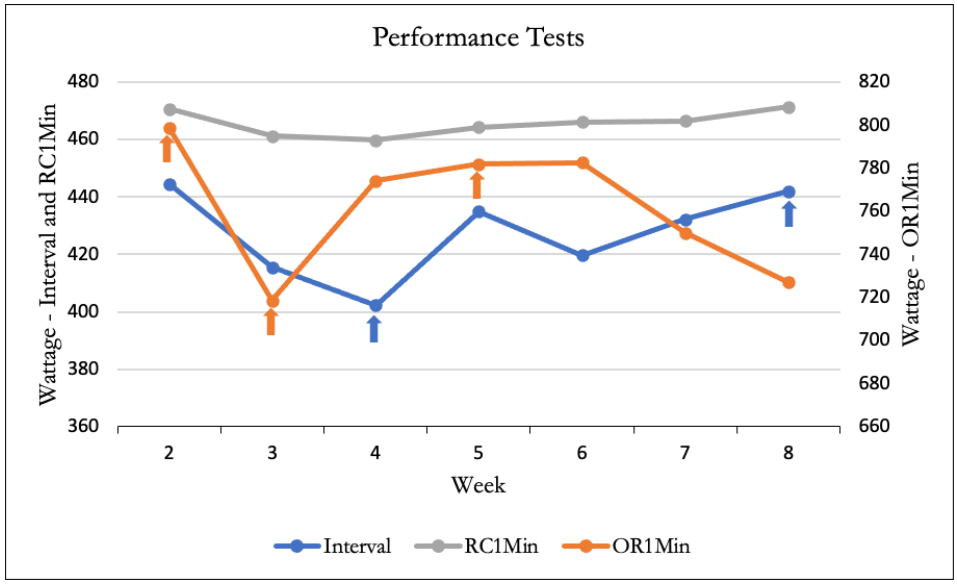
Significant differences were found in the weekly OR1-Min results ($F(1,6) = 3.392$, $p < 0.05$), with pairwise comparison finding significant decrease between Week 2 and Week 3 (M = 80.3 SD = 16.06, $p < 0.05$), and a significant increase between Week 3 and Week 5 (M = -63.3, SD = 11.60, $p < 0.05$) (Figure 3). Significant differences were also seen in the weekly Interval results ($F(1,6) = 4.555$, $p < 0.05$) with pairwise comparison indicating significant increase between Week 4 and Week 8 (402.23 ± 42.42, 442.00 ± 32.62; M = -39.77, SD = 9.943, $p < 0.05$) (Figure 3).

Figure 2. HRV (rMSSD) and TST (Minutes) over the course of the study.



Note. Intervention phase from Week 3 through Week 6.

Figure 3. All performance tests during the study.



Note. Interval and RC1Min use the left y-axis, OR1Min uses the right y-axis. Significant week to week changes are indicated by arrows: orange arrows are for OR1Min, blue arrows are for Interval test. All significance at $p < 0.05$.

Discussion

We hypothesized that increased time asleep each night would lead to improvements in ergometer performance in these male rowers. Conclusions could not be interpreted due to the lack of sleep improvements during the intervention phase. We found no change in TIB between baseline and intervention phases but a decrease of 18 minutes in TST. TIB stayed consistent at approximately eight hours for the baseline and intervention phases of the study and dropped by approximately 20 minutes during post-intervention. Baseline and post-intervention TIB were expected to be similar, therefore this difference could suggest that the baseline measurements taken were not indicative of true habitual sleep patterns for participants. A probable cause is due to baseline collection occurring during the start of the school semester when participants could take advantage of the lighter workload to get increased amounts of sleep compared to what they would normally get during the semester, thus skewing the data. Conversely, it is possible that the post-intervention phase reflected a non-habitual sleep pattern, i.e., sleeping less than normal, allowing for the possibility that the pre- and intervention phases were indicative of habitual sleep patterns. Previous research has found average TST to be 416.0 ± 22.2 minutes in elite junior rowers (TIB = 446.1 ± 16.3 minutes) and 442 ± 56 minutes in elite male rowers.[20,31] How these values relate to normal sleep times in collegiate male athletes remain unclear and future research should explore that question.

HRV behaved as anticipated based on prior research, increasing overtime to suggest a tolerance or adaptation to prescribed workload, though it did not correlate with sleep or performance. Previous research has established HRV as a proxy for recovery and adaptation to stress.[10,18,28,32] Within our population, HRV increased during the fourth and fifth week of the study, indicating a tolerance and adaptation to the workload from the coaches. During the sixth week, when the team traveled and the training load increased, we observed a subsequent drop in HRV. Despite the behavior of the HRV data (see Figure 2), no correlation was found with sleep time. HRV is influenced by many different factors, sleep and training load are only a few of these.[11,33-34] These other factors should be considered in future research.

There were significant changes in performance during the study in OR1-Min test and Interval test results. For the OR1-Min test, a significant decrease in performance was found between Week 2 and Week 3 of testing. Although it is unclear what the reasons for this might be, it possibly had something to do with the beginning of the sleep extension phase of the study. Prior research suggests improvements would be seen during and post sleep extension[7,9,35-36] but, possibly transitioning from baseline to intervention phase could have triggered stress or other factors that negatively influenced the performance on the OR1-Min. The start of the spring semester may have played an additional role, with the change from a vacation to a school schedule and workload. This seems to be further supported since performance on the OR1-Min improved close to baseline levels by Week 5 (798.80 ± 70.05, 781.80 ± 57.30), suggesting participants had adjusted to their new schedule and the stress of a new semester was not present.

Only the Interval Test showed significant differences (Week 4 and Week 8). With any repeated test of performance, improvements in test results are expected as a function of practice and familiarization with the test. Only two outcome measures (OR1-Min and Interval) showed significant differences; possible explanations for this are discussed below.

There were no performance improvements from baseline to post-intervention. Performance across all measured outcome variables remained constant or got worse with performance declining in the OR1-Min and the Interval tests between baseline post-intervention (798.80 ± 78.38 vs. 756.22 ± 152.42; 444.45 ± 41.16 vs. 434.83 ± 40.49). Since there were no significant changes made in either TST or TIB, if improvements in performance were observed, they would have been attributed expected changes due to

daily practice. Even when controlling for weight and minimizing the influence of outliers, performance still declined (Data not shown). Though impossible to determine the influence sleep had on test performance, it is worth noting that with total sleep less than the amount recommended by the National Sleep Foundation (7-9 hours), performance decreased over time, suggesting the need for a minimum amount of sleep to expect performance improvements in rowing.

A common observation throughout this study and in previous research is the poor sleep behavior and hygiene of athletes. Both Mah and Swinbourne note that their data support previous findings characterizing the poor normative sleep behavior in athletes.[7,9] Poor sleep behaviors can be the result of many factors. Lack of education seems to play a role, which includes knowledge about the importance of a consistent bedtime and individual sleep requirements. Individual requirements for sleep will change depending on the lifestyle demands of the athlete and inconsistent sleep schedules can negatively affect sleep and performance.[37-38] Education programs around individual sleep requirements and developing consistent sleep schedules have shown to be effective in producing positive effects on these indices of sleep in both men and women.[37,39] Additional factors to consider when assessing the poor sleep behavior of athletes are length and timing of sleep extension interventions, training load, and intensity.[9] Sleep times decreased during the course of the study as intensity increased or remained constant, similar to findings in over-reaching endurance athletes, suggesting disturbances in sleep quality as hard training increased.[40]

There are additional factors that could explain the lack of improvement during the intervention phase. Primary among them was the practice schedule and training plan of the participants. All participants were on the same training plan from the coaches; however it is possible that athletes were doing additional workouts on their own in conjunction with the testing. This could affect how well rested participants were for the test, influencing their performance week to week. It is important to note that this study was performed in a collegiate sports setting, which speaks to its ecological validity.

Another factor that could have contributed to the results we saw was nutrition, as diet can have a large impact on performance.[41-42] Additionally, lifestyle stress or school stress could have impacted recovery and performance of participants. During the study timeframe there were several exams for classes. Studying would have likely resulted in later nights and higher levels of stress for the participants. We could indirectly monitor stress through the daily HRV recordings for each athlete, although these cannot give specific causes of stress, merely systemic stress and how well the individuals were adapting.

Limitations

There were several limitations to this study. First, the athletes were unable to achieve the necessary time in bed and time asleep. As stated previously, this is a group with early practice times, a unique population in this research as most sports studied have afternoon or evening practices.[7-9] Our participants would have to aim for a bedtime of 8 pm each night to meet the nine hours of sleep required for the intervention. Even with napping they did not achieve the prescribed sleep during intervention. Better adherence might be possible if a study was to look at the effects of smaller increases in sleep, such as a set percent increase over baseline or a specific amount of time, or to assess time in bed rather than total sleep.

Naps have been shown to be effective as supplementing lost sleep but there is a possibility that these could have impacted adherence to strict bedtimes at night. Additionally, the sleep tracker used is designed for bedroom use; episodes of sleep that occurred during the day, such as dozing in class or microsleeps would not have been accounted for. A sensitive wrist actigraph would be able to account for and track these instances.

Second, because these are student athletes with varying class schedules, the participants self-selected the time of day they completed performance tests. This made it challenging to rule out the effect time of day has on the performance. Research suggests that later practice times will lead to improved performance due to circadian rhythm, subjective feelings of more restful sleep, or both.[43-45]

Thirdly, as this was a small participant group and we did not have a control group, it is difficult to make any determinations or conclusions based on the data collected. This was made more challenging with the data that was missing from imperfect adherence of the participants to the protocol. This missing data also decreases the power of our study. A higher study participation would have been ideal.

Finally, the performance tests used, the OR1-Min, RC1-Min, and Interval tests were all created and implemented following best practice guidelines within the sport of rowing. An alternate method would have been to track a specific workout that the head coach already had as part of the weekly practice schedule instead of implementing something additional to the training program.

Future research should include monitoring of training load and volume during the study, to control for and identify the influence of outside stressors. Non-fatiguing performance tests, such as peak power testing or vertical jump testing will be better for measuring rapid, explosive power. Additionally, tracking a consistent prescribed weekly workout of longer duration would address not having a longer duration test as part of the testing protocol. Finally, using an activity monitor would allow for greater flexibility with napping locations and recording microsleeps, in addition to providing a better gauge of total physical activity on a day-to-day basis for subjects.

Conclusions

We were unable to evaluate the impact of sleep on performance since athletes did not change their sleep during the intervention. The average sleep time for participants was less than what is recommended by the National Sleep Foundation. Despite the amount of training done, participants did not improve on any of the performance measures used. It is the author's opinion that, in sleeping less than the recommended seven to nine hours, participants hurt their recovery and continued performance over the course of the study. Coaches should include sleep education and reminders as part of their daily interactions with athletes, emphasizing the importance of a good night's sleep on their performance.

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CASE STUDY
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Multidisciplinary Assessment and Management of a Complex Patient Who Underwent Bariatric Surgery for Clinically Severe Obesity: A Case Report

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Introduction

Over 40% of American adults have obesity, defined as a body mass index (BMI) $\geq$ 30 kg/m^2).[1] Approximately 10% have clinically severe or extreme obesity, often operationalized as a BMI $\geq$ 40 kg/m^2.[1] Clinically severe obesity is seen with greater frequency among both African- and Hispanic-Americans and as compared to those of European heritage.[2] Clinically severe obesity is associated with well over 200 comorbidities, including type 2 diabetes, hypertension, heart disease, sleep apnea, osteoarthritis, and several types of cancer.[3] More severe forms of obesity also are associated with higher total health care, medical, and pharmacy costs.[4]

Lifestyle modification (which traditionally includes caloric restriction, increased physical activity, and behavioral modification instruction), pharmacotherapy, and bariatric surgery are the obesity treatment approaches supported by the most robust empirical evidence.[5-6] Bariatric surgery is advised for persons older than 18 years and with a BMI $\geq$ 40 kg/m^2 or those with a BMI $\geq$ 35 kg/m^2 in the presence of the significant weight-related comorbidities noted above.[7]

Bariatric surgery is considered the most effective treatment for extreme obesity, producing large and durable weight losses far superior to those seen with non-surgical treatments.[3] Patients typically reach their maximum weight loss of 20-35% of body weight in the first year after surgery.[8-9] Weight losses of this magnitude are associated with significant improvements in morbidity and mortality, even after accounting for the risks associated with the surgical procedure.

Like all evidence-based obesity treatments, bariatric surgery is underutilized. Approximately 250,000 individuals are believed to undergo bariatric surgery in the United States annually, representing only 1% of Americans who meet the BMI criteria.[10] African- and Hispanic-Americans, those persons most likely affected by severe obesity, comprise only 25% of individuals who undergo bariatric surgery, representing a profound health disparities issue. The underutilization is likely the result of a number of factors, including insurance coverage, access to quality medical care, weight stigma and bias, as well as suboptimal patient-provider communication.[11-12]

Multidisciplinary Assessment of Candidates for Bariatric Surgery

Individuals interested in bariatric surgery undergo an intensive preoperative evaluation process. This includes an initial informational session with the multidisciplinary team followed by individual consultations with the surgeon, nurse practitioner, and registered dietitian. Prospective patients then complete monthly medical weight management counseling visits with the dietitian or nurse practitioner, with the frequency and duration typically determined by third-party payers.[13] During this time, other recommended preoperative evaluations and assessments, including evaluations of cardiac and gastrointestinal functioning as well as sleep apnea, are also completed.

Most programs and third-party payers also require that patients undergo a mental health evaluation preoperatively. These evaluations are performed by psychologists or social workers who are part of the bariatric surgery team or who work as external consultant to the program. This evaluation serves several purposes.[14-15] First, it is used to identify significant mental health issues (e.g., substance misuse or poorly controlled depression) that may contraindicate surgery. The evaluation also is psychoeducational in nature, as provides an opportunity to help the patient understand the environmental and behavioral contributors to the development of extreme obesity and, more importantly, provide education on the dietary and behavioral requirements of the procedure.

Here, we present a case report describing the preoperative, multidisciplinary assessment and postoperative management of a complex patient who underwent bariatric surgery. As she was enrolled in a prospective research study investigating the relationship between preoperative psychosocial functioning on postoperative outcomes, we have robust psychometric data to augment the clinical report. We highlight the role that members of the multidisciplinary team played in her care and also discuss where other disciplines could have been consulted to support an optimal postoperative outcome.

Case Report: Preoperative Presentation

The patient was a 46-year-old African-American woman. She reported a height of 5'3" with a weight of 280 pounds, yielding a BMI of 49.6 kg/m^2. She reported an 8th grade education. She stated that she was single and living with her romantic partner. She reported an adult child living outside of the home. She was unemployed and receiving social security disability.

The patient reported struggling with her weight since the age of 25. Since then, she had experienced steady weight gain, with larger gains following her pregnancy and the start of psychiatric medications for bipolar disorder. She reported that her mother was overweight; she described her father as thin. She reported one brother, who had normal weight, and one sister, who had obesity before she died in her 30s.

In a self-report questionnaire, the patient reported that eating large portions and eating an excessive amount of fried foods regularly may have contributed to her weight gain over the past two decades. In response, she reported that she had engaged in several self-directed weight loss attempts using meal replacement shakes and cutting back on portion sizes. She reportedly did not lose weight from these attempts and was unable to sustain these behavior changes over time. She denied current symptoms of binge eating or night eating. She denied a history of inappropriate compensatory behaviors, such as self-induced vomiting or laxative misuse.

She reported that she had started to make changes to her eating habits in advance of surgery. She had begun to drink meal replacement shakes up to 3 times per day. However, she also reported that she had continued eating unhealthy foods such as fried chicken and macaroni and cheese. She had been unable to completely stop eating these types of foods, but she was making an effort to reduce the frequency with which she ate these foods.

Additionally, the patient reported poor sleep and sleep habits, going to bed between 6-7 PM and rising at 1-2 AM. She also stated that she did not eat in the summer, just drinking water each day. Despite being pressed by the program's dietitian, the patient continued to deny that she ate during the warmer months.

Upon direct questioning during her mental health evaluation, the patient described her mood as "alright." She described fluctuating levels of depressive symptoms since the death of her sister 11 years ago. At that time, she began treatment with an outpatient psychotherapist as well as a psychiatrist and she has been involved in this level of treatment consistently since that time. A psychometrically validated assessment of depressive symptoms suggested moderate symptoms of depression. She reported regular suicidal ideation, stating she feels this way most of the time, but later retracted this statement and said she feels suicidal about once per month. Upon further questioning, she explained that she had no plans to act on these thoughts and would not carry these thoughts out because she wanted to be here for her family. She reported that her relationship with her partner was a significant stressor and trigger of her depressive episodes.

The patient reported a history of drug abuse (cocaine) for more than 20 years, but that she stopped using 4 years ago and has not used since. She stated that she discontinued her drug use without any specific substance abuse treatment; her main motivation was to save money. She also reported that she smoked cigarettes for over 30 years and quit 2 months ago.

The mental health professional contacted the patient's therapist, who confirmed that she has been working with the patient for the past 3 years on a biweekly basis. The therapist reported that the patient has been drug-free for the past 4 years and believes her to be at low risk for relapse. She noted that the patient had not expressed any suicidal ideation to her, but planned to discuss her articulation of those thoughts to the mental health professional from the bariatric team with her during their next session. Overall, the therapist believed that the patient was an appropriate candidate for surgery.

As noted above, the patient was enrolled in a research study investigating the relationship between preoperative psychopathology and postoperative outcomes. Thus, additional objective assessments of her mental health functioning was available. These findings were separate from her clinical care and confidential, so they were not accessible to the surgery team. Based on a structured psychiatric interview, she met current diagnostic criteria for pervasive depressive disorder and bipolar disorder II. She was diagnosed with a lifetime history of a stimulant/cocaine use disorder. Her urine drug screen was negative. She reported no symptoms of an eating disorder. Her responses to a patient-reported outcome measure suggested very poor health-related quality of life.

Over the next several months, the patient completed all of the standard preoperative medical assessments required by the program and attended all preoperative medical weight management visits. She was scheduled for surgery in October 2016. However, she did not attend her final preoperative visit, which led to surgery being cancelled. She was rescheduled to undergo surgery in December 2016, but did not present for her final preoperative appointment. The patient contacted the surgery office to reschedule surgery and ultimately underwent a sleeve gastrectomy in February 2017. Ultimately, the preoperative assessment process took 218 days; on average this assessment period takes 195 days.[16]

Psychosocial Status of Candidates for Bariatric Surgery

The last two decades have witnessed a profound growth in the research that has investigated the psychosocial status of candidates for bariatric surgery. The typical candidate is a woman in her mid-40s. Only 20-30% of candidates are from underserved groups. Most patients report at least a high school education; it is relatively rare to have a patient who reports less than a high school education. Such cases intuitively raise concern about the candidate's ability to make the dietary and behavioral changes required of surgery. Approximately 30-40% of candidates report unemployment at the time of their initial evaluation; up to 40% report public health insurance.[17]

At least eight studies have investigated rates of psychopathology in candidates for surgery using structured diagnostic interviews.[15,18-24] Taken together, these studies are indicative of increased psychiatric vulnerability among persons who present for bariatric surgery. Lifetime rates of any psychiatric diagnoses ranged from 36.8%-72.6%; current diagnoses were less common, reported in 20.9%-55.5% of candidates.

Mood disorders are the most commonly seen condition. In the study which included the present case, current mood disorders were diagnosed in 7% candidates for surgery and 44% reported a lifetime history of mood disorders.[24] Approximately 40% of candidates for bariatric surgery report current mental health treatment,[25-26] a percentage higher than typically reported in the general population. Most of this treatment is provided by psychiatrists, psychologists, and licensed clinical social workers.

Up to 50% of candidates for bariatric surgery report some form of disordered eating.[27] While our patient presented with very disorganized eating behaviors and reported consuming an unhealthy diet, she likely was not a reliable historian of her daily eating intake. However, the team was in consensus that she did not meet diagnostic criteria for an eating disorder.

Approximately 10% of candidates report a history of substance use disorders.[21,28] Current substance use is seen in less than 2% of candidates for bariatric surgery; an active disorder is a contraindication to bariatric surgery.[7,29]

There is a strong relationship between obesity and quality of life.[30-32] Individuals often report significant difficulties with physical (walking, climbing stairs) and occupational functioning.[33] While patients present for these issues with some frequency, few are referred to physical, occupational, or recreational therapists pre- or postoperatively.

Case Report: Postoperative Course

Postoperative visits with the bariatric surgery team are routinely scheduled for 6 weeks, 3 months, 6 months, and 12 months in the first year, and annually thereafter. The patient presented here did not complete her initial follow-up visit with the bariatric surgery team after being discharged from the hospital. She did not respond to repeated calls from the team to check on her status.
Twelve weeks postoperatively, she called the program complaining of nausea and vomiting. She was scheduled for an appointment the next day, which she did not attend. She eventually came into the office and reported an inability to consume anything by mouth coupled with daily vomiting. She was admitted the hospital and diagnosed with a stricture, a narrowing of her sleeve. The stricture was dilated, and the patient was rehydrated and discharged after two days. While the patient was encouraged to follow up as an outpatient, she cancelled two scheduled appointments and did not arrive for a third. The patient did not respond to additional attempts to contact her.

The patient did attend her postoperative research study visits at 6-, 12- and 24 months. At 6 months, she weighed 193 lb., which was a 31% loss from her preoperative weight. At 12 months, she lost 35% of her body weight, which is considered a somewhat larger than expected weight loss.[8-9] While a subset of patients report some weight regain between the first and second year, our patient regained 33% of her weight during those 12 months, a much greater weight gain than typically seen.[8-9]

The patient had a positive drug screen for marijuana at months 12 and 24. Her psychiatric meds were changed several times over the first two postoperative years. The patient acknowledged inconsistent use of these medications and infrequent attendance at regularly scheduled psychotherapy appointments with her therapist. Her eating behavior remained very disorganized. While she never met diagnostic criteria for an eating disorder, she clearly was challenged to follow the recommended postoperative diet.

Over time, her assessor concluded that the patient was a poor historian and inconsistent reporter of her own behavior. As a result, her research data, which included several implausible responses, was censured. However, she remained in need of clinical management by the bariatric team.

Postoperative Weight Loss and Psychosocial Outcomes

Up to 25% of patients who undergo bariatric surgery regain a clinically significant amount of weight in the first few postoperative years.[8-9] The reasons for this are not well articulated but likely involve some combination of physiological and behavioral variables. Weight regain is associated with deterioration of many of the health benefits associated with bariatric surgery and raises concerns about the need for adjunctive treatment, such as nutritional and/or mental health counseling.[34-35]

Success following bariatric surgery also requires chronic adherence to a rigorous, reduced calorie diet. Patients are encouraged to eat meals that are dramatically smaller than they consumed prior to surgery, eating no more than 1200-1500 kcal/d on average.[5] Consuming large amounts of food at a given meal, or drinking beverages while eating, can trigger nausea and/or vomiting, as seen with the patient described here. Many patients cannot tolerate certain foods, particularly those high in fat content, as they may trigger vomiting or diarrhea, both of which can be physically and psychologically uncomfortable. As the patient was a poor historian, it was difficulty to clearly identify which foods triggered her vomiting or whether it was the result of the surgical stricture.

Lack of regular follow up with the bariatric program also has been associated with suboptimal outcomes and weight regain.[36-38] Regular follow-up, as well as engagement in monthly support groups, provides an opportunity to promote engagement in the behavioral and dietary changes necessary for success. Our patient, unfortunately, was challenged to keep regularly scheduled appointments. We suspect that her low level of formal education and her mental health history contributed to her inconsistent attendance at scheduled appointments.
A number of studies have found that the presence of a mood disorder is associated with smaller postoperative weight losses.[39-41] Mood disorder symptoms often improve, at least initially, with weight loss. This may have been the case with our patient, but her inconsistent engagement with the bariatric team made that difficult to confirm.

There is great concern about the increased risk of substance abuse after surgery. Our patient had a history of substance abuse and tested positive for marijuana at both the 12 and 24 month postoperative assessments. She endorsed symptoms of alcohol misuse on the patient reported outcome measures used in the research study, but denied using alcohol at all during the accompanying interviews. Her history of substance abuse, coupled with her inconsistent reporting, left the clinical team concerned that she may have been abusing other substances, but this was unable to be confirmed.

Summary

This case represents some of the clinical complexity and challenges common to bariatric care. The patient's BMI and medical history made her an appropriate candidate for surgery. However, her lack of formal education intuitively raised concerns about her ability to fully understand the dietary and behavioral requirements of surgery and appropriately engaged in postoperative care. This was a valid concern and, over time, the team concluded that she was a poor historian and unreliable reporter. While such observations could lead some to conclude that she was not an appropriate candidate for surgery, many patients who present for surgery have very complicated psychosocial histories. Others may not have the ready availability of cognitive or tangible resources, or stable social support, believed to be critical to promoting long-term success. While the team worked diligently to re-engage her in postoperative care, as did her therapist, the patient was challenged to take advantage of those resources.

Despite these complexities, the patient did experience a clinically significant weight loss and anticipated improvement in her physical health. While the size of the weight regain in the second postoperative leads to concern about her ability to maintain a clinically significant weight loss in the future, she is healthier today than she would have been otherwise. Weight loss treatment with a more conservative approach, such as lifestyle modification or use of a weight loss medication approved by the Food and Drug Administration, would have been unlikely to promote a weight loss of this size. While engagement in postoperative care, or use of a specific behavioral and psychotherapeutic intervention postoperatively, would likely increase the odds that she will maintain her weight over time and improve her nutrient intake, her psychosocial issues appear to prevent her from engaging in those treatments.

Weight regain and impairments to one's ability to eat in a typical fashion after bariatric surgery often leads to criticism of the surgical treatment of obesity and skepticism about its use on larger number of individuals. Nevertheless, it is important to remember that even a suboptimal loss of 20% of initial body weight is superior to that typically seen with non-surgical treatment. A loss of that magnitude often decreases the risk of morbidity and mortality. In addition, it often leads reduced health care costs. In cases like this, the multidisciplinary team is challenged to generate novel strategies to promote engagement and long-term success for the individual patient. While this case included psychologists,

nurses, and dietitians—professionals typically involved in bariatric care—we wonder if engagement with a social worker, occupational therapist, or recreational therapist may have beneficial to the patient postoperatively. Some bariatric programs have professionals with expertise in physical activity on the multidisciplinary team. Perhaps the number of Americans with clinically severe obesity and who may present for bariatric surgery in the future warrants consideration of regular participation of these professionals and with the goal of promoting the best possible postoperative outcomes for the largest number of patients.

Disclosures and Conflicts of Interest

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Evaluating the Parenting of Caregiving Grandparents

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Background and Purpose: *In Philadelphia, approximately 14,000 grandparents are caring for over 16,000 grandchildren. The SOWN GrandFamily Resource Center (GFRC) provides social services and parenting education for low-income, caregiving grandparents in the Philadelphia area. This project investigates whether grandmothers participating in the GFRC report changes in parenting on the annual Department of Human Services (DHS) Parenting Collaborative pre- and post-survey.* ***Methods:*** *Selected survey questions from the DHS Parenting Collaborative survey were grouped into subscales measuring social support and positive parenting practices. Associations between social support and parenting were examined using Pearson's correlation coefficient, and average subscale scores and percentage of grandparents demonstrating positive parenting practices were compared between 16 matched pre- and post-surveys using paired t-tests and McNemar's tests, respectively.* ***Results:*** *McNemar's tests determined that changes in the proportion of grandmothers demonstrating positive parenting for each practice from pre- to post-survey were not statistically significant, with p-values between .625 and 1. The change in mean score for nurturing behavior from pre- to post-survey was statistically significant, $t(15) = -2.21$, $p = .04$. Social support had a moderate, statistically significant, positive association with all parenting measures.* ***Conclusion:*** *Participants averaged 3.7 years of GFRC participation at the time of the pre-survey and demonstrated high levels of initial knowledge and parenting practice, but not a significant change from pre to post. The positive association between social support and parenting practice is supported by research that a caregiver's distress negatively impacts parenting.* ***Social relevance:*** *Large numbers of grandparents are raising their grandchildren. Understanding the needs of grandparent-headed families and effective ways to provide support is important for the wellbeing of the grandparents and grandchildren involved.*

Keywords*:* grandfamilies, parenting, custodial grandparents, caregiving grandparents

Introduction

In 2019, over 14,000 grandparents in Philadelphia were serving as the primary caregiver for over 16,000 grandchildren, with 40% of the children having neither parent present.[1] Nationally, approximately 2.3 million grandparents were serving as the primary caregiver (caregiving grandparent) for 2.7 million grandchildren in 2019.[1] Grandparents caring for grandchildren are more likely to experience depression and anxiety and tend to have higher levels of stress than their non-caregiving peers.[2]

The SOWN GrandFamily Resource Center (GFRC) provides weekly, hour-long, professionally facilitated support groups for primarily low-income, caregiving grandparents in the Philadelphia area. Support groups are on-going, and caregiving grandparents are eligible as long as they live with and are the primary

caregiver for one or more grandchild. While the majority of participants are caregiving grandmothers, GFRC programs have expanded to include grandfathers caring for their grandchildren as well. Both telephone groups and in-person groups at community and health centers are available. Individual counseling is also provided on an as-needed basis, as well as referrals for other services. The support groups are designed to empower participants to help themselves and each other. Parenting education is a central topic of the GFRC program. The purpose of this project was to determine whether grandmothers participating in the GFRC report parenting changes as a result of the GFRC program using the written, self-report Department of Human Services (DHS) Parenting Collaborative pre-survey (administered every September) and post-survey (administered in June).

Methods

Out of 21 grandmothers who completed the pre-survey between 2015 and 2018, 16 completed the post-survey and were included in this study. Participants attended an average of 2.5 GFRC group sessions per month. See Table 1 for participant demographic information.

Table 1. Demographic Description of Grandmother Caregivers

Characteristic	Mean	(SD)	Count	%
Age (n = 16)				
Min: 51.1	65.8	(8.6)		
Max: 82.1				
Years in service at SOWN (n = 16)	3.7	(3.5)		
Number of grandchildren (n = 16)	1.6	(0.6)		
1 grandchild			8	50%
2 grandchildren			7	44%
3 grandchildren			1	6%
Race/Ethnicity (n = 16)				
African American Black			16	100%
Marital Status (n = 16)				
Single			12	75%
Married			3	19%
Widowed			1	6%
Education (n =16)				
High school			11	69%
Post high school/ some college			1	6%
College and/ or graduate school			4	25%

Selected questions from the 46-item DHS Parenting Collaborative survey were grouped into subscales measuring social support and parenting practices around nurturance, discipline, and communication. The parenting practices and specific questions were selected in collaboration with the GFRC coordinator and the SOWN Director of Programs to be the most relevant to the focus of GFRC parenting education. The subscales have not been validated. See Table 2 for a more detailed description of the subscales and questions.

Table 2. Description of Parenting Behavior Subscales

Subscale	Description	Subscale Description
Discipline	Use of positive discipline techniques (e.g., discipline based on learning for the future rather than punishment for the past)	**Subscale: 2 questions** Sample question: I praise my child when he/she behaves well.
Nurturance	Quality of caregiver-child relationship: positive atmosphere, acceptance, emotional support, playing with or reading to child[4] (see note)	**Subscale: 4 questions** Sample question: I spend time with my child doing what he/she likes to do.
Communication	Listening to each other and talking things through	**Subscale: 3 questions** Sample question: When we argue, my family listens to "both sides of the story".
Social Support	Having someone available to talk to	**Subscale: 3 questions** Sample question: I have others who will listen when I need to talk about my problems.

Note: Smith GC, Hayslip B, Hancock GR, Strieder FH, Montoro-Rodriguez J. A randomized clinical trial of interventions for improving well-being in custodial grandfamilies. J Fam Psychol. 2018 Sep 1;32(6):816–27.

Question responses were Strongly Disagree (1) to Strongly Agree (4) (no Neutral). Questions were reverse scored as necessary so that answers corresponding to 3 or 4 indicated a positive response. Subscale scores were computed by averaging the responses to the questions included in the subscale (after reverse scoring) and ranged from 1 to 4. Higher scores on each subscale indicate a more positive outcome. Scores of 3 and above on parenting scales were considered to indicate positive parenting practice. The mean scores for all participants for each subscale were compared between pre- and post-surveys using paired t-tests. The proportion of grandmothers demonstrating positive parenting practice for each scale from pre- to post-survey was compared using a McNemar's test. The correlations between the mean scores for social support and each parenting subscale were also examined using Pearson's correlation coefficient.

Results

The results include 16 grandmothers completing pre-and post-surveys. Respondents indicated a high level of positive parenting on the pre-survey. Each parenting subscale had a mean score of at least 3 with at least 75% of grandmothers demonstrating positive parenting (scoring a 3 or higher). The increase in the mean score for nurturance from pre- to post-survey was statistically significant ($p = .04$). The results for each subscale are shown in Table 3.

Table 3. Comparison of Parenting Behaviors from Pre- to Post-Survey

Parenting Behavior	Pre-Survey		Post-Survey		Paired t-tests comparing means	McNemar's Tests for proportions
	Mean	% with score ≥ 3	Mean	% with score ≥ 3		
Nurturance (n = 16)	3.17	75%	3.39	100%	$t(15) = -2.21$, $p = .04$*	$p = .13$
Discipline (n = 16)	3.56	93.8%	3.28	81.3%	$t(15) = 1.71$, $p = .11$	$p = .50$
Communication (n = 15)	3.17	87.5%	3.24	93.3%	$t(14) = -0.68$, $p = .51$	$p = 1.0$

According to McNemar's tests, the changes in the proportion of grandmothers with positive parenting practices were not statistically significant; however, it is notable that the proportion showing nurturing behavior increased from 75% on the pre-survey to 100% on the post-survey (Table 3). Social support had a moderate, positive association with all three parenting measures, meaning that higher levels of social support were associated with higher levels of positive parenting. The association was statistically significant at the $p < .05$ level for all three parenting measures (Table 4).

Table 4. Pearson's Correlation Coefficient (r) Between Social Support and Parenting Behaviors

	Nurturance (n = 16)	Discipline (n = 16)	Communication (n = 15)
Social Support	$r(14) = .69$ $p = .003$	$r(14) = .53$ $p = .030$	$r(13) = .54$ $p = .036$

Conclusion and Social Relevance

One possible explanation for the increase in nurturance is that a caregiver's own distress may interfere with offering emotional support. Improving parenting practices such as discipline could lead to a less stressful relationship, enabling caregivers to provide more emotional support. The positive association between social support and parenting practice is supported by research that a caregiver's distress has a negative impact on parenting[3] as more social support is likely to reduce distress. Addressing distress by increasing social support may also by itself have a positive impact on parenting. SOWN's focus on social support and parenting education is a promising combination for improving parenting among caregiving grandparents.

Participants demonstrated high levels of parenting practice on the pre-survey. One reason for this could be that participants averaged 3.7 years of GFRC participation at the time of the pre-survey, so the pre-survey was not a true pre-test. This makes it difficult to measure the impact of the GFRC program, but high scores on the pre-survey could be due to program participation. Because parenting education is a

focus of the GFRC program, the fact that the grandmothers included in this study stayed in the program for an extended time implies that the program is relevant and beneficial to participating caregiving grandmothers.

In order to further study parenting changes due to the GFRC program, a control group of caregiving grandparents not participating in the GFRC who take the same pre- and post-survey would be beneficial. In addition, administering the pre-survey to participants when they enroll in the GFRC instead of at a set time of year would provide more accurate pre-test results. Finally, the number of participants included in this study was small and homogeneous which does not allow generalization to all grandparent caregivers. More research is needed to determine the most effective way to promote positive parenting practices among caregiving grandparents.

Large numbers of grandparents are raising their grandchildren, often without a parent involved. Understanding the needs of these grandparent-headed families and evaluating programs to ensure they are effective is important for the wellbeing of the grandparents and grandchildren involved.

Disclosures and Conflicts of Interest

There are no conflicts of interest to report. These data were previously reported in poster sessions at the College of Physicians Poster Presentation, February 15th, 2019, and the Temple University College of Public Health Research Day, April 5th, 2019.

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NARRATIVE REVIEW
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Public Health Protection Against Bioterrorism via Respiratory Pathogenic Viral and Bacterial Agents using Protective Face Masks

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The widespread respiratory transmission of the SARS-COV-2 virus has taught the general public the role that face coverings can play in mitigating the spread of the virus. While vaccines will mitigate widespread viral infection, protective face masks are an important way to prevent respiratory infections from various pathogenic agents. In view of the possibility of respiratory-based bioterrorism or new naturally occurring pathogens in the future, it is possible that the public may have to become comfortable with universal usage of face masks. The Centers for Disease Control recommends that all families have readily available respiratory protection as part of their personal pandemic plan and face masks should be worn by all individuals during a pandemic especially one caused by bioterrorism or an emerging viral or bacterial pathogen. This paper discusses the evolution of protective face masks that capture pathogens, development of face mask filters which enhance the performance of cloth-based protective facemasks for capturing pathogenic respiratory particles, and protective face masks with filters which capture and kill or deactivate pathogens using silver, copper oxide and zinc oxide-based particles.

Keywords: bioterrorism, public health, face mask

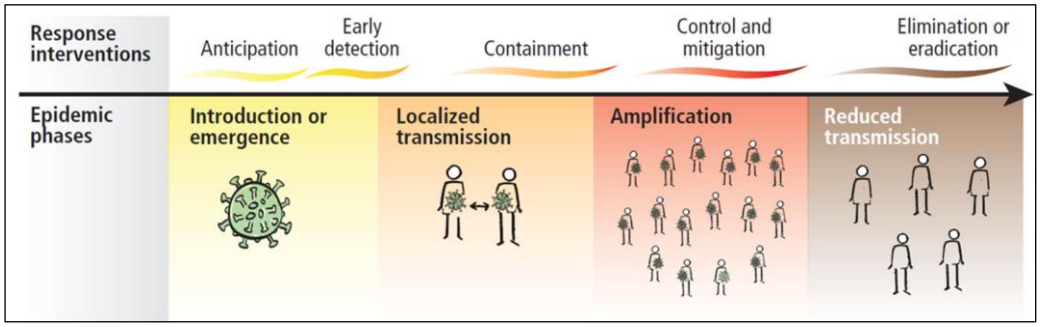
Introduction

Infectious disease disasters are events that involve a biological agent or disease and that can result in mass casualties, such as a bioterrorism attack, a pandemic, or an outbreak of an emerging infectious disease. Infectious disease disasters are different from other types of disasters because they increase the risk of communicable disease spread during and after the incident. Infectious disease disasters include biological terrorism, emerging infectious disease outbreaks, and other pandemics. Common characteristics of this diverse group of biologic agents include the ability to be dispersed in mucosalivary aerosols of 1 to 5 micron-sized particles, which can penetrate the distal bronchioles. Further, once a human is infected by a pathogenic virus it can be transmitted to other humans though respiratory means. There is a high likelihood of such a pandemic occurring in the future and bioterrorism, which is the intentional use of a biological agent or derivative of such an agent to inflict harm or death onto a civilian population, also could occur.[1] Bacterial or viral pathogens can be weaponized and the biologic agents may be dispersed by several techniques including aerosol sprays.[2]

In 2018, the World Health Organization published a handbook titled "Managing Epidemics".[3] The handbook offered several critical suggestions. Effective and rapid containment of emerging diseases is just as vital as early detection in order to avoid a large-scale epidemic. Rapid containment should start as

soon as the first case is detected regardless of the etiology, which is most likely to be unknown. It requires skilled professionals to safely implement the necessary countermeasures. Pre-training of these professionals is essential to guarantee the safety and efficiency of the operations. Once the infectious disease threat reaches an epidemic or pandemic level, the goal of the response is to mitigate its impact and reduce its incidence, morbidity, and mortality as well as disruptions to economic, political, and social systems.[3] (See Figure 1)

Figure 1. Epidemic phases and response interventions



The transmission of pathogenic aerosols can be reduced by wearing face coverings. Different types of coverings offer different degrees of protection. The ultimate goal is to minimize penetration through the porous material of the covering. Penetration usually takes place due to a pressure and concentration gradient across the barrier, respectively. Pathogens, such as the SARS-COV-2 virus, are transmitted most easily through liquids such as mucosalivary aerosols.[4] These aerosols can be expressed by coughs, sneezes, or just exhaling.[5] For respiratory pathogens, such as viruses or bacterial, the best way to prevent localized infection and/or mitigate community spread (amplification) are effective protective textile face masks since they can reduce and mitigate airborne transmission. No masking maximizes exposure whereas universal masking results in reducing the exposure via inhalation and transmission via exhalation.

Protective face masks, at the minimum, should provide adequate cover of the wearer's mouth and nose. Further, they should provide a tight fit while still remaining comfortable. Their function is to minimize or even prevent pathogenic-containing mucosalivary secretions from passing through the mask during exhalation and also minimize or even prevent pathogenic respiratory aerosols or droplets exhaled by others from being inhaled. This is referred to as "capturing ability". However, capturing ability, while necessary, is not sufficient to prevent infection from a pathogenic agent. To be optimally effective in mitigating spread of respiratory borne diseases, the mask should also deactivate or kill the pathogenic agents. The ideal mask would be able to both capture and deactivate or kill either of these types of pathogenic agents. Further, the protective mask should be reusable for a period of time and be able to be occasionally cleaned using conventional laundering equipment. The protective mask should have an adequate shelf life so it can be held in reserve for immediate deployment in case of a public health threatening bioterrorism event or a transmission of a naturally occurring emerging pathogen. (See Table 1)

Table 1. Mask Mechanisms to Mitigate Airborne Aerosol Spread of Pathogens

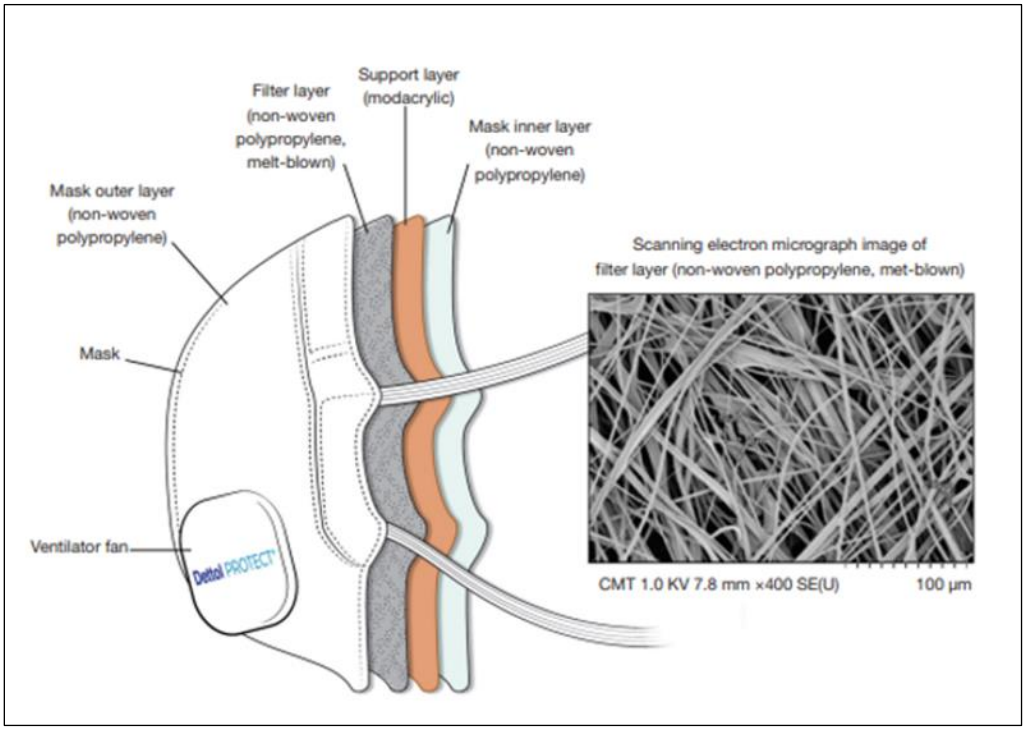
RESPIRATORY FUNCTION	MASK MECHANISM		OPTIMAL MASK MECHANISM
INHALATION	CAPTURE	DEACTIVATE OR KILL	CAPTURE AND DEACTIVATE OR KILL
EXHALATION	CAPTURE	DEACTIVATE OR KILL	CAPTURE AND DEACTIVATE OR KILL

Evolution of Protective Face Masks That Capture Pathogens

An N95 respirator, which is widely recognized as the "gold standard" face covering by medical professionals, is designed to achieve a very close facial fit and very efficient filtration of airborne particles. The edges of the respirator are designed to form a seal around the nose and mouth. N95 respirators are commonly used in healthcare settings. They are tested for fluid resistance, filtration efficiency (particulate filtration efficiency and bacterial filtration efficiency), flammability and biocompatibility.[6]

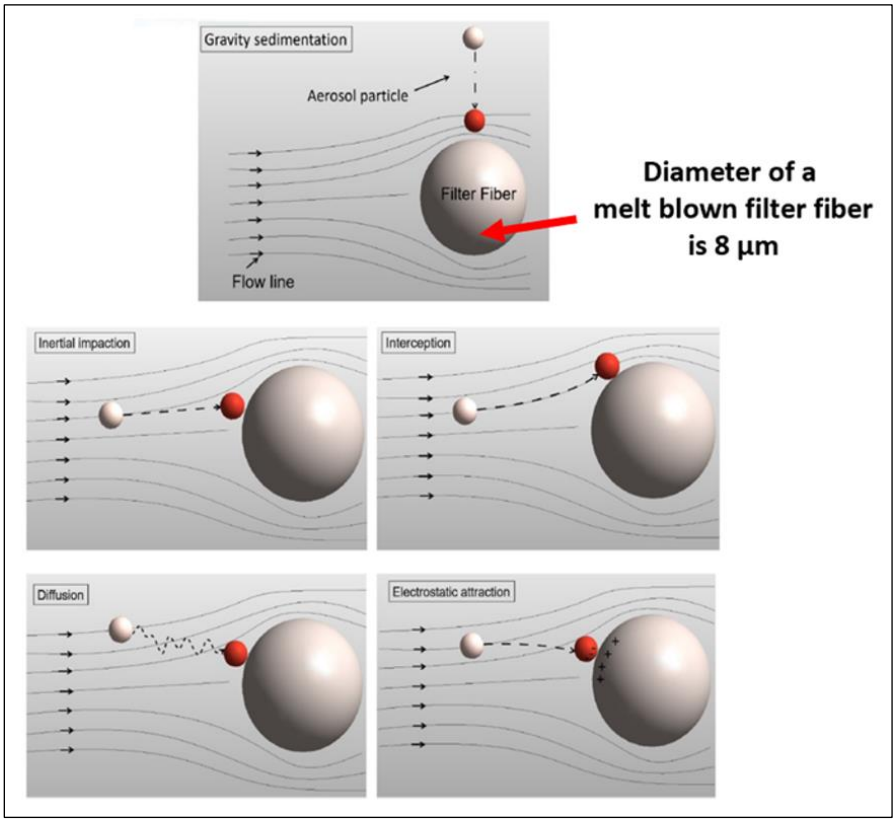
An N95 respirator removes particles from the air that is breathed through it. These respirators filter out at least 95% of very small (<0.3 micron) particles. N95s are capable of filtering out all types of particles, including bacteria and viruses.[7, 8](See Figure 2) Melt blowing is a method of producing fibers on the order of 10 μm using high production rates without using spinnerets. A thermoplastic polymer is melted and extruded through relatively large holes. As the polymer leaves the extrusion holes it is hit by a high stream of hot air which breaks up the fiber flow and stretches the filaments until they are relatively fine. At a later stage, cold air mixes with the hot air and the polymer solidifies into a fiber.

Figure 2. Schematic of Various Fabric Layers in an N95 respirator



The N95 filter that is included in the N95 respirator is solely designed to capture particles containing pathogens, such as SARS-COV-2, and not deactivate or kill the pathogens. Capturing these particles is a result of 5 different mechanisms: gravity sedimentation, inertial impaction, interception, diffusion, and electrostatic attraction (See Figure 3).[9]

Figure 3. Schematic of the Mechanisms of Aerosol Penetration Through Masks



During the initial stages of the SARS-COV-2 pandemic, the use of cloth masks, many of them homemade, became widely prevalent as commercial masks were not readily available. The efficiency of common fabrics used for cloth face masks made from woven fabrics was recently evaluated.[10] The study presented data of Particulate Filtration Efficiency (PFE) and pressure differential (ΔP) which is an indication of breathability. The PFE is measured using ASTM Standard F2299 "Standard Test Method For Determining The Initial Efficiency Of Materials Used In Medical Face Masks To Penetration By Particulates Using Latex Spheres."[11] For maximizing wearer breathability during exhalation and inhalation, the pressure drop should be as low as possible while maintaining a relatively high particle filtration efficiency. A face mask with relatively high filtration efficiency but physiologically intolerable resistance to airflow is essentially unusable to the wearer. Consequently, both the filter penetration and air resistance should be considered when ranking protective face masks and respirators.

Protective face masks which are purposed to capture aerosolized pathogenic agents should have relatively high-Particulate Filtration Efficiency (PFE). Using the recent data of aerosol filtration efficiency of common fabrics used in respiratory cloth masks from Konda et al. the PFE and pressure drop across the mask material were determined for N95 respirators, surgical masks and a range of woven fabrics for particle sizes < 0.3 µm and > 0.3 µm (See Table 2).[12]

These data indicate that protective face masks made from surgical masks and conventional cloth fabrics have relatively lower filtration rates than N95 respirators. Nonetheless, N95 respirators and surgical masks are superior to the woven fabric cloth masks that were studied. Fit (how tight the seal is between a mask and the wearer) also plays an important role with regard to affecting the PFE (See Table 3).[12]

Table 2. Particle Filtration Efficiencies of Various Test Specimens at a Flow Rate of 1.2 CFM and the Corresponding Differential Pressure (ΔP) across the Specimen

Type of Mask	Particle Filtration Efficiency (PFE), %		Pressure Differential (ΔP), Pa	Comparisons of PFE to N95 melt blown polypropylene filter respirator	
	Particle Size			Particle Size	
Particle Size	<0.3 µm	>0.3 µm		<0.3 µm	>0.3 µm
N95 Respirator-melt blown polypropylene fiber	85	99.9	2.2		
Surgical Mask -spun bonded polyester	76	99.6	2.2	89.4%	99.7%
Quilter's Cotton – 2 woven layers	38	49	2.5	44.7%	49.0%
Quilter's Cotton – 1 woven layer	9	14	2.2	10.6%	14.0%
Flannel -65% cotton/35%polyester	57	44	2.2	67.1%	44.0%
Chiffon – 90% polyester/10% cotton – 1 woven layer	67	73	2.7	78.8%	73.0%
Chiffon – 90% polyester/10% cotton – 2 woven layers	83	90	3.0	97.6%	90.0%
Silk – 1 woven layer	54	56	2.5	63.5%	56.0%
Silk – 4 woven layers	86	88	2.7	101.2%	88.0%

Table 3. Particle Filtration Efficiencies of Various Test Specimens at a Flow Rate of 1.2 CFM and the Corresponding Differential Pressure (ΔP) across the Specimen (No Gap v. Gap)

Type of Mask	Particle Filtration Efficiency (PFE), %		Pressure Differential (ΔP), Pa	Comparisons of PFE to N95 melt blown polypropylene filter respirator	
	Particle Size			Particle Size	
Particle Size	<0.3 µm	>0.3 µm		<0.3 µm	>0.3 µm
N95 Respirator-melt blown polypropylene fiber (No Gap)	85	99.9	2.2		
N95 Respirator-melt blown polypropylene fiber (Gap)	34	12	2.2	40.0%	12.0%
Surgical Mask -spun bonded polyester (No Gap)	76	99.6	2.5	89.4%	99.7%
Surgical Mask -spun bonded polyester (Gap)	50	44	2.5	58.8%	44.0%

Table 4. Comparison of surgical masks to 100% cotton T-Shirts for B atrophaeus and Bacteriophage MS2 bacterial agents

***B atrophaeus* bacterial agent**			
Mask Material	**Bacterial Filtration Efficiency (BFE), %**	**Pressure Differential, ΔP (Pa)**	**Comparisons of BFE to spun bonded surgical mask**
Surgical Mask -spun bonded polyester	**96.4**	**5.23**	
100% Knitted Cotton T-Shirt fabric – 1 layer	**69.4**	**4.29**	**72.0%**
100% Knitted Cotton T-Shirt fabric – 2 layers	**70.7**	**5.13**	**73.3%**
Bacteriophage MS2 bacterial agent			
Mask Material	**Bacterial Filtration Efficiency (BFE), %**	**Pressure Differential, ΔP (Pa)**	**Comparisons of BFE to spun bonded surgical mask**
Surgical Mask -spun bonded polyester	**89.5**	**5.23**	
100% Knitted Cotton T-Shirt fabric – 1 layer	**50.9**	**4.29**	**56.9%**

The efficacy of homemade cloth masks made from knitted cotton fabric, compared to surgical masks, was assessed to determine if they would be effective in an influenza epidemic (H1N1). The results of the study, which compared the bacterial filter efficiency (BFE) and pressure drop, are seen in Table 4.[13] The efficacy of homemade cloth masks made from knitted cotton fabric, compared to surgical masks, was assessed to determine if they would be effective in an influenza epidemic (H1N1).[13] The results of the study, which compared the bacterial filter efficiency (BFE) and pressure drop, are seen in Table 4. Bacterial agents were used as proxies for the H1N1 virus, and the data indicate that homemade masks made from knitted cotton fabric should not be used for the reduction of transmission from diseases which can be transmitted via mucosalivary secretions.

Tables 2, 3, and 4 suggest the relative ineffectiveness of masks made from cloth fabrics without filters. Further, the importance of a tight fit between the wearer and the mask is apparent.

Development of Face Mask Filters to Enhance the Performance of Cloth-Based Protective Face Masks for Capturing Pathogenic Mucosalivary Particles

The particle filtration efficiencies of protective masks made from common woven or knitted fabrics have been shown to have a minimal effect in the filtration of mucosalivary secretions such as those from persons infected with viral and bacterial pathogens. Hence, there is a need to enhance the filtration capability of cloth masks. This can be accomplished with the incorporation of textile materials specifically designed to filter particles such as those expressed by either wearer exhalation or inhalation. Since protective face masks made from conventional woven or knitted fabrics are minimally effective in containing droplets and aerosols when compared to the N95 respirator which has a middle layer comprising a melt blown fibrous filter face mask developers are now recognizing the importance of fibrous filters to substantially reduce the transmission of respiratory induced particles.

Particulate filters have been used in a wide range of other applications. For example, in 1976 a patent was issued for the production of fibrous filters, which was directed at spinning solutions which are electrostatically sprayed and deposited continuously onto a gas permeable band-form support.[14] In 2006, a study determined the filtration efficiency of the most penetrating aerosol particles in melt blown fibrous

filters and nano-electro spun fibrous filters.[15] Nano-electrospinning is a fiber production method which uses electric force to draw charged threads of polymer solutions or polymer melts up to fiber diameters in the order of less than 1 μm. Electrospinning uses an electrical charge to draw very fine (typically on the micro or nano scale) fibers from a liquid or polymer solution. Using the procedure for determining the particle filtration efficiencies, four different filters were studied with fiber diameters of 10 μm, 2 μm, 0.7 μm, and 0.1 μm. The researchers found "*that utilization of nanofibers to manufacture air filters seems to be an excellent solution from the standpoint of the filter efficiency improvement, especially if the process target is removal of sub micrometer-sized aerosol particles, usually being the hardiest (sic) to filter out*."[15]

Nano-electrospinning has emerged as an effective technique for the fabrication of micro and nanoscale objects, and it is particularly useful in the fabrication of fibrous filters. In the fabrication of filters, nano-electrospinning has an advantage over traditional technologies, such as melt-blowing, of operating at room temperature. Another significant advantage, and one that is unique to electrospinning, is its ability of producing fibers in the submicron scale. As such, due to their submicron diameter they have a substantially higher surface area to volume ratio than fibers that are produced using the melt blowing process and, as such, are considered more efficient filters.[16]

Researchers in Singapore recently reported that a key factor that affects the function of air filter is fiber diameter and when it is reduced to nanoscale (<1μm) the surface area to volume ratio is relatively high and results in a more effective filter. Nanoscale fibers are commonly produced by nano-electospinning of electrically charged polymer solutions.[17] There are now many protective face mask manufacturers supplying products with insertable nanoscale fiber filters. For example, HaloMask™, offers one with an insertable nanofiber filter.[18] The nanofiber filters were tested for Bacterial Filtration Efficiency (BFE), Differential Pressure (ΔP) and Particle Filtration Efficiency (PFE). Below are the data for BFE and ΔP obtained by the manufacturer of HaloMask™ using ASTM standards.[19,20]

Table 5. Bacterial Filtration Efficiency and Particle Filtration Efficiency of HaloMask™

Bacterial Filtration Efficiency (BFE)	Pressure Differential, ΔP (mm H_2O/cm^2)	Test Method
~98%	~2.0	ASTM F2101-19
Particle Size	**Particle Filtration Efficiency**	**Test Method**
0.1 μm	~ 99.0%	ASTM F2299/F2299M – 03
0.3 μm	98.8%	ASTM F2299/F2299M – 03
0.5 μm	97.8%	ASTM F2299/F2299M – 03
1.0 μm	98.0%	ASTM F2299/F2299M – 03

Masks with Filters Which Capture and Kill or Deactivate Pathogens

While filtration of pathogenic respiratory agents is necessary to minimize airborne transmission, when filtration is also coupled with pathogenic deactivation a protective face mask will significantly minimize infection of the wearer and thus also minimize transmission to others. Pathogenic deactivation can be affected by various metal-based elements and compounds which can be incorporated into masks or mask filters.

Silver Particle-Based Deactivation of Pathogens

A study in the early 2000's was directed at the antimicrobial effect of surgical masks coated with nanoparticles.[21] The study assessed the antimicrobial activity of nanoparticles (consisting of a mixture of silver nitrate and titanium dioxide) and nanoparticle-coated facemasks to protect against infectious agents. *Escherichia coli* and *Staphylococcus aureus* were used for this study as both are reference strains used for antimicrobial susceptibility testing. The researchers found that masks coated with nanoparticles at low concentrations were effective against *E. coli* and *S. aureus*, and that bacteria attached to the surface of nanoparticle-treated masks were killed completely. An earlier study showed that impregnation, instead of coating the medical device with nanoparticulate silver metal, improved the antimicrobial activity of the device. This is probably due to the slow and continual release of silver that prolonged the antimicrobial effect.[22] As such, silver-based antimicrobial formulations and nanoparticles have been identified as effective antibacterial agents.[23,24] In 2011 it was reported that silver nanoparticles have mainly been studied for their antimicrobial potential against bacteria, but have also proven to be active against several types of viruses including human immunodeficiency virus, hepatitis B virus, herpes simplex virus, respiratory syncytial virus, and monkey pox virus.[25]

Silver-based nanoparticles have been incorporated and functionalized in polyester/cotton fabrics using pad-dry-cure method (a common textile fabric coating process).[26] This composite proved to be effective for inhibiting the SARS-COV-2 virus, decreasing the number of replicates in 99.99% after an incubation period of 2 minutes. In addition, it caused 99.99% inhibition of the bacterial pathogens *S. aureus*, *E. coli* and *C. albicans*, preventing cross-infections and does not cause allergies or photo irritation processes, demonstrating the safety of its use.[25]

Copper Oxide-Based Deactivation of Pathogens

Impregnation of copper oxide into respiratory protective face masks endows them with potent anti-influenza biocidal properties without altering their physical barrier properties such as breathability. Further, the use of biocidal masks may significantly reduce the risk of hand or environmental contamination, and thereby subsequent infection, due to improper handling and disposal of the masks. The masks were challenged with virus (H1N1) or an aerosolized avian influenza virus (H9N2). The mean (5 masks were tested) Bacterial Filter Efficiency (BFE) was 98.2 %.[27]

Zinc Oxide Particle-Based Deactivation of Pathogens

Zinc oxide nanoparticles are antibacterial and inhibit the growth of microorganisms by permeating into the cell membrane. The oxidative stress damages lipids, carbohydrates, proteins, and DNA.[28] With regard to the antiviral effect of zinc oxide nanoparticles a study was done on the inhibition of H1N1 virus infection.[29] Zinc oxide nanoparticles and polyethylene glycated zinc oxide nanoparticles were studied. The study showed that polyethylene glycated zinc oxide nanoparticles had a stronger antiviral effect than just zinc oxide nanoparticles.

A patent was recently issued which discloses how zinc oxide nanoparticles can be applied using ultra sonics to coat fabrics.[30] The patent is being using by Sonovia Ltd. in Israel to produce the SonoMask.[31] The SonoMask has been tested to be 99.35% effective against SARS-COV-2, an ability to filter 91% of 3μm and 95% of 5μm particles and be able to withstand at least 55 laundering cycles. As such, the SonoMask both captures and deactivates viral pathogens. Further, since the SonoMask can be reused many times it does not significantly contribute to environmental waste.

Another possibility for creating mask filters which both capture and deactivate viral and bacterial borne pathogens involves nano-electro spinning nanofibers (which have a relatively high surface area to volume ration), such as polyvinylidene difluoride (PVDF) or polyacrylonitrile (PAN), and including in them nanoparticles such as zinc oxide or silver which deactivate viral pathogens and kills bacterial pathogens

Conclusions

The potential for bioterrorism events that are a result of aerosolized viral and bacterial pathogens exists. We have learned from the SARS-COV-2 pandemic how dangerous aerosolized viral pathogens are and while eventually vaccines may be developed to mitigate the spread of new pathogens, effective protective face masks are an important element that can mitigate the immediate continuous spread and containment of the pathogen. While at first the only widely available masks were cloth-based they proved to be substantially ineffective when compared to the "gold standard" N95 respirator. As the pandemic continued many researchers and companies developed masks that, at first, were only effective in capturing the pathogenic aerosol. Capturing the aerosols with face masks, while useful for protecting the public health, are not as effective until they can also deactivate or kill the pathogen. The CDC recommends that all families have readily available respiratory protection as part of their personal pandemic plan because face masks should be worn by infected individuals when in public places during a pandemic.[32] This would especially true during a bioterrorism induced pathogenic pandemic or the emergence of new naturally occurring pathogens including SARS-COV-2 variants.

The United States has seen approximately 1500 deaths per million (1.5 in a 1000) of its population as of late February 2021 while Canada has only seen about 580 deaths per million of its population.[33] American failures have remained dramatic as such questions as wearing masks and how to relax lockdowns have been bitterly politicized.[34] As such, if the U.S. public is ever threatened by respiratory aerosol pathogen-based bioterrorism attack or another pandemic from an emerging virus, the public will have no choice but to adopt universal mask usage or face the consequences of wide spread infection and death.

Finally, speaking during an online briefing by the WHO in late December 2020, Dr. Mark Ryan, Head of the WHO Emergencies Programme, said that other emerging diseases could be more dangerous than SARS-COV-2. Dr. Ryan said:

> This pandemic [SARS-COV-2] has been very severe, it has spread around the world extremely quickly and has affected every corner of this planet - **but this is not necessarily the big one**. This virus is very transmissible and it kills people and it has deprived so many people of loved ones but its current case fatality is reasonably low compared to other emerging diseases. This is a wakeup call, we are learning now how to do things better. How to do science better, how to do logistics better, how to do training better, how to do governance better, how to communicate better.[35]

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