6. Results
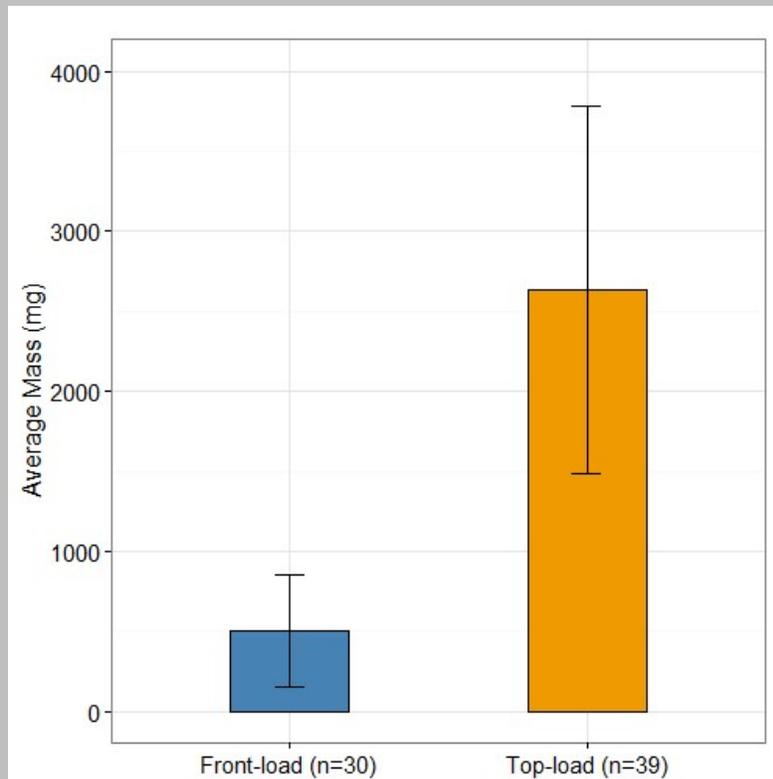
6.1 Treatment Effects

6.1.1 Washing Machine Load Type

Fiber mass captured in Front-load and Top-load washing machine samples were compared to determine if washing machine type had an impact on shedding (Figure 6.1). A Mann-Whitney U test found that median fiber mass of Top-load wash samples (median = 2574.6 mg, n = 39) was significantly larger than Front-load wash samples (median = 536.7 mg, n = 30; Z = 6.60, $p <$ 0.001). This difference amounted to Top-load treatment samples having approximately 430% more fiber mass than Front-load samples across all garments on average.

Figure 6.1   Jackets washed in top-load machines shed roughly 430% more fiber mass.
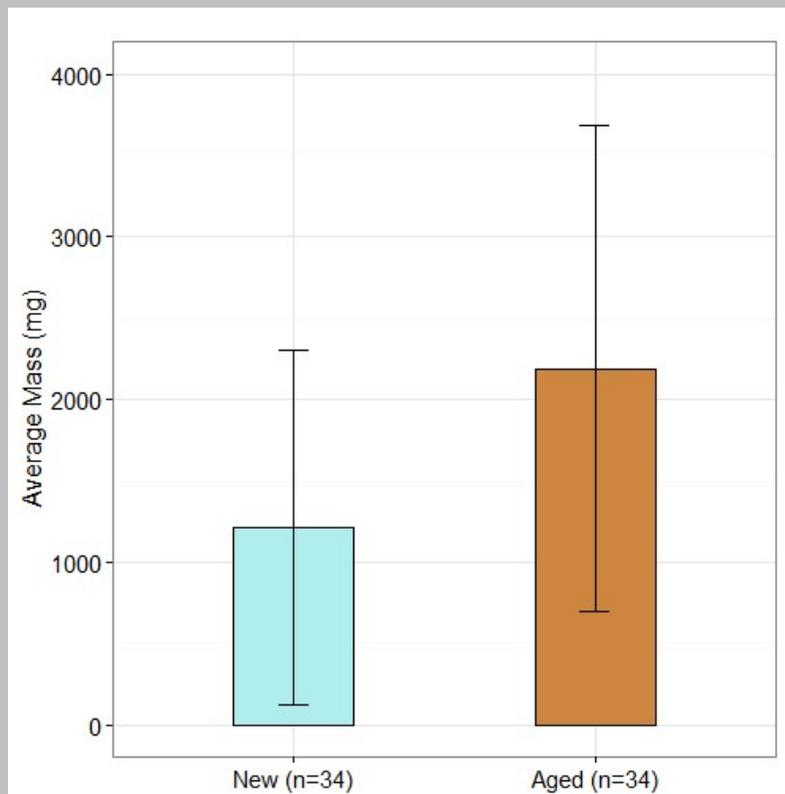

Average combined fiber mass shedding per wash for all trials by Front-load (n = 30) and Top-load (n = 39) washing machines. Error bars are ± one standard deviation.

6.1.2 Jacket Aging

New and Aged treatment trials were compared to determine the effect of aging on jacket shedding (Figure 6.2). On average, aged jackets shed approximately 80% more than new jackets. A Wilcoxon-Signed Rank test was performed to test the median fiber release of the jackets before and after simulated aging. The median fiber mass release of Aged jackets (median = 2523.7 mg, n = 34) was significantly larger than New jackets (median = 1126.1 mg, n = 34; Z = 3.98, p < 0.001). Visual inspection of the jackets after the simulated aging process identified fraying (in Jacket E in particular), which may be related to the increased jacket shedding after aging treatment.

Figure 6.2

Aged jackets shed roughly 80% more fiber mass than New.

Average combined fiber mass shedding per wash for all trials by new treatment (n = 34) and aged treatment (n = 34). Error bars are ± one standard deviation.

6.1.3 Jacket Aging and Washing Machine Load Type

To further explore the effects of treatment type on fiber mass, shedding was compared among four combinations of treatments: New jacket Front-load wash, Aged jacket Front-load wash, New jacket Top-load wash, and Aged jacket Top-load wash (Figure 6.3). Mann-Whitney-U tests revealed that among New treatment garments, Top-load (median = 1773.8 mg, n = 19) and Front-load samples (median = 210.9 mg, n = 15) had significantly different medians (Z = 4.29, p < 0.001). This significant difference also held true comparing washing machine type for aged jackets as well (Z = 6.08, p < 0.001).

Figure 6.3   Fiber mass shed per jacket based on washing machine and aging treatment combinations.
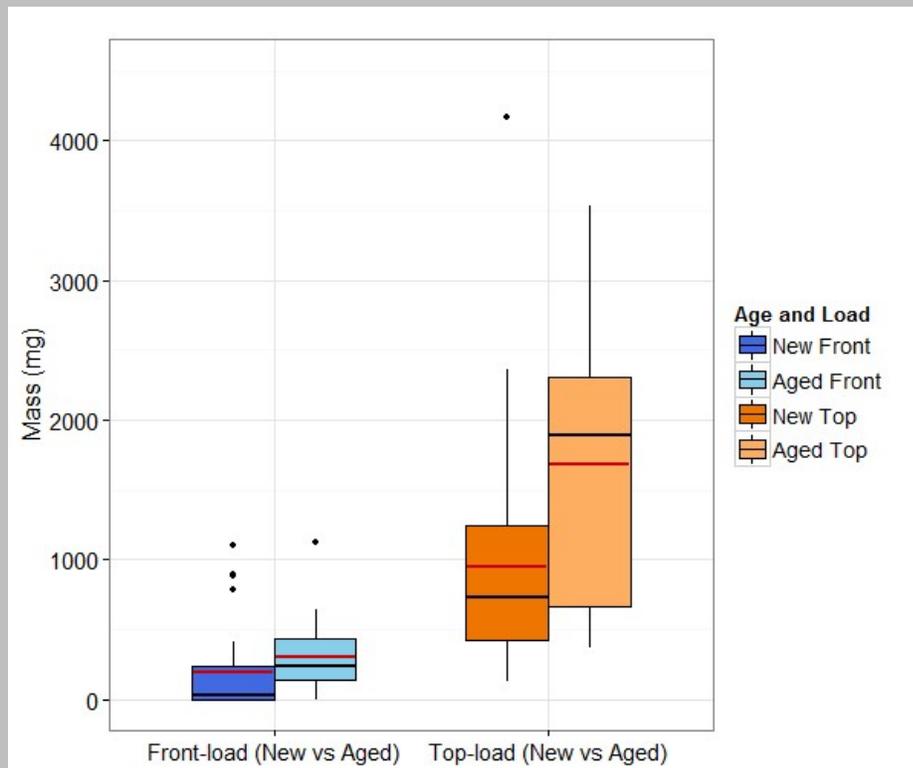
Total fiber mass shedding per wash for load and aging treatment combinations. Lighter boxes indicate aged samples. Medians are indicated by black lines and means are shown as red lines. Outliers are represented by black points.

In regards to aging between the two washing machine types, a Wilcoxon-Signed Rank test found a significant difference in median fiber mass shed per garment in Top-load machines between New (median = 1773.8 mg, n = 19) and Aged jackets (median = 3465.4 mg n = 19; Z = 3.46, p <

0.001) but Front-load machines did not have this same significant difference in aging treatment ($Z = 1.24$, $p = 0.107$). This may indicate that the aging process has more of an influence on shedding in Top-load washing machines than Front-load washing machines. To further test this possible effect, a Multi-way ANOVA was conducted on the interaction of age and washing machine type with jacket type, age, and load included as covariates, finding a significant interaction between the two treatment types on fiber mass shed ($F(1) = 17.43$, $p < 0.001$).

6.2 Jacket Comparisons

6.2.1 Average Shedding

Shedding between each jacket type was compared by analyzing the median masses from all trials and between different treatment types (Figure 6.4). A Kruskal-Wallis test with post-hoc analysis (if significant) was performed to compare the effect of jacket type on fiber shedding across the five jacket types between aging and washing machine type treatments. Median fiber mass between jacket types did not differ significantly across all trials ($\chi^2 = 3.53$; $p = 0.47$) nor in Aged, New, and Top-load treatment. In Front-load washing machines, however, median fiber mass differed significantly ($\chi^2 = 10.32$; $p = 0.035$). Post-hoc analysis revealed that the Budget jacket had significantly different median shedding than the Patagonia C jacket. Compared across all other jackets in Front-load washing treatment, this amounted to Budget shedding an average of about 90-200% more than all Patagonia jackets. In Top-load samples, although Budget jacket shed the most, it only shed an average of about 10-40% more than all other jackets.

Figure 6.4   Average jacket shedding for all 14 trials.
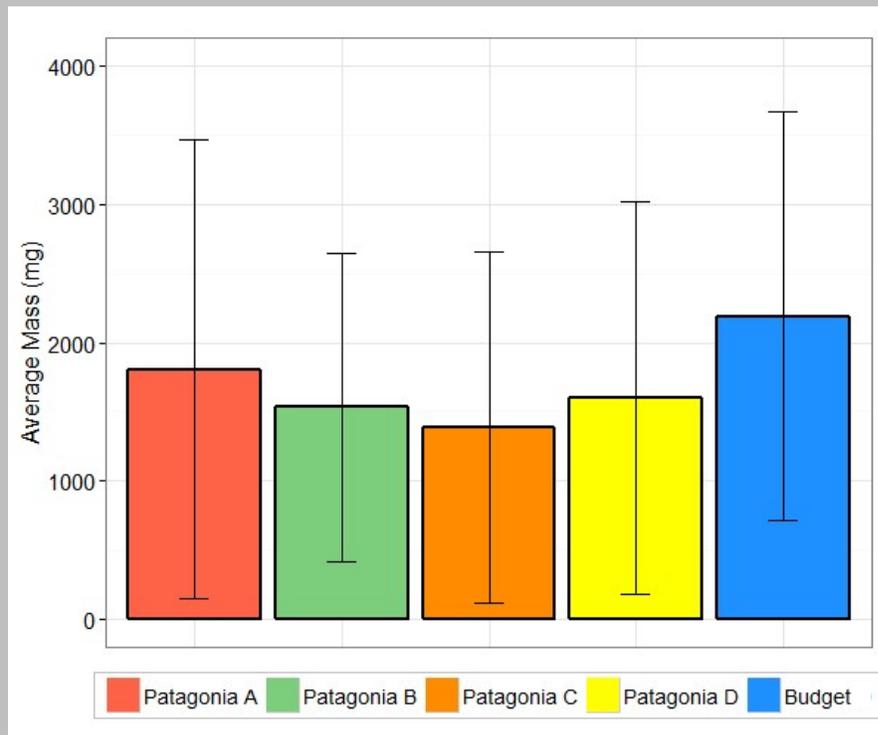
Average total fiber shedding per wash for all 14 trials of each tested jacket. From left to right jacket averages displayed are Patagonia A, B, C, and D, as well as Budget. Error bars are ± one standard deviation.

6.2.2 Normalized Jacket Averages

Jacket fiber mass shed was normalized by the original mass of the garment to obtain the percent of jacket mass shed as microfibers. This normalization may provide further understanding of how the material and construction of each jacket specifically contributes to fiber shedding across treatment types (Table 6.1). After normalization, Kruskal-Wallis tests were conducted as before. None of the jackets across any treatment grouping were significantly different from each other ($p > 0.05$), suggesting that the amount of material may contribute to fiber shedding (Table 6.2).

Table 6.1	Normalized percent total fiber mass shed by each jacket type for different combinations of wash trials by age and machine type.				
Load type, age	Patagonia A	Patagonia B	Patagonia C	Patagonia D	Budget
New Top (mg)	0.580%	0.392%	0.357%	0.248%	0.368%
New Front (mg)	0.046%	0.062%	0.007%	0.045%	0.216%
Aged Top (mg)	0.874%	0.501%	0.771%	0.605%	0.785%
Aged Front (mg)	0.206%	0.096%	0.145%	0.090%	0.117%

| Table 6.2	Average fiber mass shed by each jacket type for different combinations of treatment types of aging and washing machine type.				
Load type, age	Patagonia A	Patagonia B	Patagonia C	Patagonia D	Budget
New Top (mg)	2234.3	2077.8	1396.7	1452.6	2015.1
New Front (mg)	175.9	328.7	26.0	262.0	1179.7
Aged Top (mg)	3365.9	2656.7	3013.8	3544.0	4291.8
Aged Front (mg)	792.5	509.2	568.4	529.5	638.3

6.3 Fiber Size Capture

6.3.1 Overview

Fiber size is a characteristic of particular interest since size can affect a fiber's distribution and ecological impact. The accumulation of fibers smaller than 333 μm in clumped pills may result in the collection of small fibers on the larger mesh size. Regardless, these two mesh sizes give some insight into the approximate size of shed fibers. Comparison of these fiber sizes gives us insight into the characteristics of shedding by the jackets (Figure 7.7).

Median fiber mass per garment for 20 μm (median = 304.7 mg, n = 69) and 333 μm (1048.1 mg, n = 69) mesh sizes were compared with a Wilcoxon Signed-Rank test. Median fiber mass was found to be significantly larger on 333 μm meshes than on 20 μm meshes for paired filters (Z = 5.73 p < 0.001).

Figure 6.5

Approximately 125% more fiber mass shed onto 333 μm filters than 20 μm filters.
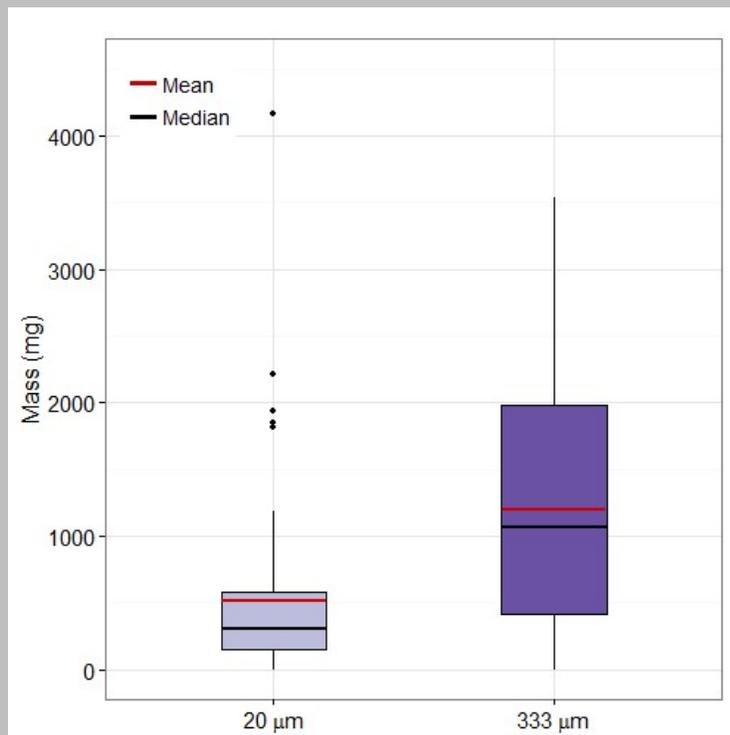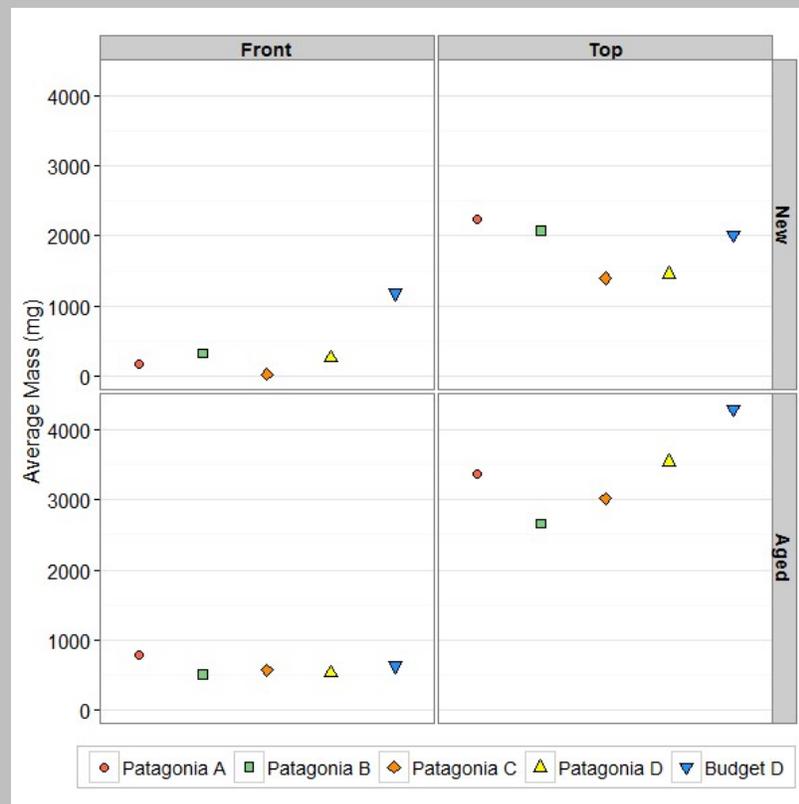

Fiber mass shed per garment for all trials on 20 μm (n=69) and 333 μm (n=69) mesh sizes. Black lines indicate medians and means are shown as red lines. Black points represent outliers.

6.4 Overview of Results

Comparing average fiber mass shed between jackets and treatment types has provided further insight into the effect of washing machine type, aging, and jacket type (Figure 6.6). Notable differences included the massive increase in jacket shedding for jackets washed in Top-load washing machines as compared to Front-load and the approximate doubling of fiber shedding after aging. In addition, shedding between jacket types varied widely, ranging from 1386.8 mg to 2191.5 mg on average. Further research and analysis of these variables may help clarify relationships and provide better understanding of their influence on jacket shedding.

| Figure 6.6 | Effects of all treatments on microfiber shedding. |

Effect of load type and age on average fiber mass shed per garment for all jacket types. Red circles represent Patagonia A, Green squares Patagonia B, orange diamonds Patagonia C, yellow triangles Patagonia D, and blue triangles Budget.